USAID FIRMS PROJECT

Investor Information Package- Hazara

Institutional Support to Khyber Pakhtunkhwa Mineral Development Department

June, 2014

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Abstract:

The landscape of Khyber Pakhtunkhwa with an area of 74,521 km2 is dominated by mountainous terrains. The province has almost all varieties of mineral resources and other natural endowments. Most of the potential areas of minerals have abundant resources of water bodies in the form of rivers and streams providing suitable sites for hydel power generation to meet the need of mining industry. The people of the region being talented in nature are a source of man power for development of natural endowments including minerals.

The Minerals Development Department, Khyber Pakhtunkhwa deals with the management of mineral resources of the province in terms of exploration promotion and grant of mining concessions to potential investors. The Department has developed this document with a purpose to attract investment by identifying various highly potential exploration-targets in District Chitral and incentives from the Provincial and Federal Governments. The main concept is to provide comprehensive information to the prospective investors in establishing exploration and mining ventures in the Khyber Pakhtunkhwa. The Khyber Pakhtunkhwa province welcomes the world to become its partners in benefitting from its multiple mineral resources and trigger mutually beneficial economic growth.

Commencing January 21st, 2014, the consultant was contracted to provide institutional support to the Government of KP to create a business friendly environment in order to increase the contribution of minerals to the economy of KP, while enforcing maximum local value addition and responsible environmental stewardship and SOPs for the purpose.

The Government of Khyber Pakhtunkhwa through its Minerals Development Department is willing to undertake all endeavors to offer its virtually untapped mineral sector to the investors. It is hoped that the present document will find a wide range of investors, both national and international.

Acronyms

AIDAB	Australian International Development Assistance Bureau
DGMM	Directorate General Mines & Minerals, Khyber Pakhtunkhwa
EL	Exploration License
EPD	Exploration Promotion Division
GEMAP	Gold Exploration and Mineral Analysis Project
KP	Khyber Pakhtunkhwa
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MDD	Minerals Development Department
MKT	Main Karakorum Thrust
MMT	Main Mantle Thrust
MTL	Mineral Testing Laboratory
Pan con	Panned Heavy Mineral Concentrate
PIDC	Pakistan Industrial Development Corporation
PMDC	Pakistan Mineral Development Corporation
SDA	Sarhad Development Authority
SOW	Scope of Work
SSZ	Southern Suture Zone
WA	Western Australia

AIDAB Australian International Development Assistance Bureau
DGMM Directorate General Mines & Minerals, Khyber Pakhtunkhwa
EL Exploration License

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Executive Summary

The Khyber Pakhtunkhwa province of Pakistan, having 74,521 km^2 area is dominated by mountainous terrain in the northern parts, while flat to mountainous in the south. The altitude ranges from 150 meter in D.I .Khan to 7690 meter in Tirich Mir, Hindukush ranges in Chitral.

Geologically the area falls in very interesting environment, having collisional, subduction, and Island arc environments together with sedimentary and meta - sedimentary crystalline fold and thrust belts. The geological environment of the region can be compared with other favorable mineral producing regions of the world e.g. Indonesia, Australia, USA etc. The region is blessed with diversity of mineral resources, and most of the potential mineral areas have sufficient water in the form of rivers and streams for hydel power generation to meet the mining industries requirements.

The Mineral Development Department (MDD) of Khyber Pakhtunkhwa has the sole responsibility of development of the mineral sector of this province as managed under an independent Directorate General Mines & Minerals (DGMM). The DGMM, having three functionary divisions, comprises of Licensing Division, Exploration Promotion Division and Inspectorate of Mines & Minerals. The function of Exploration Promotion Division is to explore and assess the minerals, licensing division deals with grant of mineral concessions, and Inspectorate of Mines is responsible for mine safety and welfare of mineworkers.

So far sufficient exploration data has been accumulated, and lying in DGMM in the form of reports and maps. However, the data has not been utilized to progress to mining for profit, to the extent expected, especially for metallic minerals. In order to provide equal and transparent opportunity to the mineral investors, the department has engaged relevant geoscientific expertise to prepare this information package based on past exploration work which identified various mineral exploration targets in Hazara Division in the mid-nineties. A new Mineral Policy of the Province has also been launched designed to create a mineral business friendly atmosphere in the province. The Khyber Pakhtunkhwa Government welcomes all the investors of the world to join hand in development and exploitation of the mineral resources of this region for mutual benefit

1. General Description of Hazara Division

1.1 Geographic Description

On the Khyber Pakhtunkhwa map, Hazara division is located to the north - east, covering more than 12000 km2 area represented by Survey of Pakistan 1:250,000 Topo sheets No 43-A, 43-B, 43-C , 43-E, 43-F and 43-G. The area has steep, rugged topography and the altitude is moderate to high starting from 335 meter at Haripur and reaching 5,290 meter at Malika Parbat peak in the north. Hazara lies in Central Eastern Himalayan region. Indus is the main river passing through districts Kohistan, Batagram, Mansehra and Haripur. Kunhar River passes along the eastern boundary of the region at Kaghan valley, district Mansehra. The high altitude valleys i.e. Jalkot, Kandia and Kaghan are snow covered in winter and serve as perennial sources of water. Abbottabad is the divisional head quarter, and the well populated city of the division. Hazara division occupies both sides of Karakorum High Way (KKH), the road transport artery between Pakistan and China. Abbottabad, Galiat (collective name for hill resorts, such as Nathiagali and Baragali between Abbottabad and Murree) and Kaghan/Naran valleys are the famous spots of tourism. KKH passes through Hazara division, and enters Gilgit Baltistan (GB) to the north, continuing into China through the Khunjerab pass. The people of the Hazara region are hard working, friendly and mining oriented. Both skilled and unskilled manpower is available.

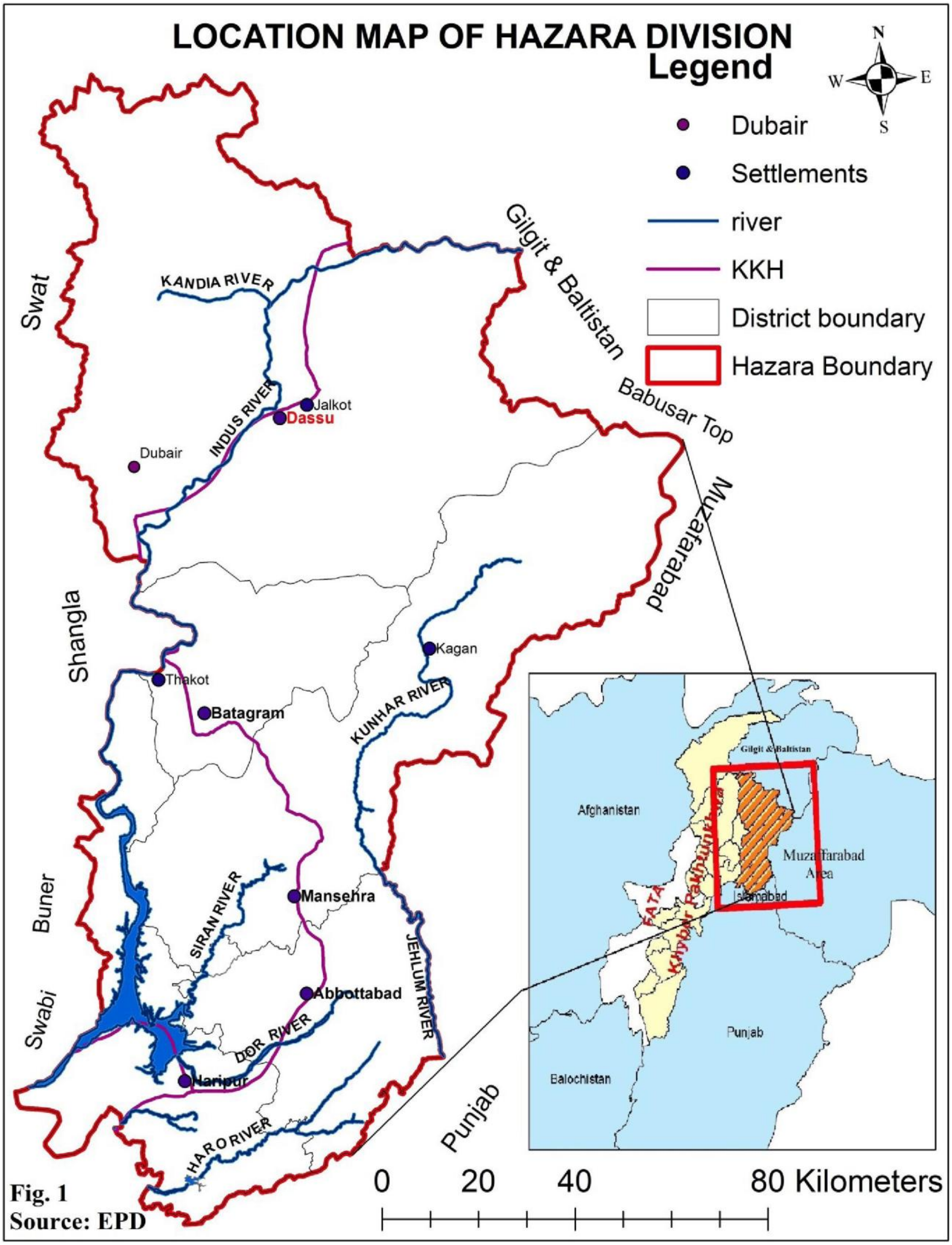


Figure 1 Location Map of Hazara Division

1.2 Infrastructure and Accessibility

The infrastructure, in shape of roads, communication, water resources, schools and hospitals, is fair. Road access from Islamabad (capital of Pakistan) is all weather metalled road known as Karakorum High Way (KKH). From towns located on KKH, roads branch out to different valleys. Train links Havelian rail head (in the southern part of Hazara division) via Taxila and Rawalpindi, to the sea port at Karachi, about 1100 km aerial distance to the south. Islamabad and Peshawar international airports link Hazara to the rest of the world.

1.3 Climate

Climatically, almost all of Hazara lies in the Monsoon range with warm to cool temperatures and rainy season in summer, while cold in winter, with heavy snow falls in the upper ranges. The area has thick forests and vegetation at slopes/gullies in districts Mansehra, Batagram and Kohistan.

1.4 Exploration and Mining History

The area is geologically well studied in the past for academic and research work. The earliest published geological work of Hazara is that of Waagen and Wynne (1872) who studied the stratigraphy of a part of Abbottabad. Another early paper is by Middlemiss (1896). These early workers established the broad structural – stratigraphic relationships in the area and named several of the rock units. Wadia (1931) applied the name "Syntaxis" to the sharply curving mountain structure in the eastern half of the area. An initial reconnaissance survey of Southern Hazara was made in 1961 by S.T. Ali, Calkins and Offield. The Mansehra quadrangle was mapped (1961-1962) by Offield, Abdullah and Zafar. Field work in the Garhi Habibullah quadrangle and a part of Hazara was done by Calkins during 1962, 1963 and 1964. Offield and Abdullah completed work in the Balakot and Mahandri quadrangles in 1962. Offield, Calkins and Afaq Ali completed work in the Tarbela quadrangle in 1964.

Soapstone deposits at Kohala were described by F. L. Klinger (1963). A geological survey of Tarbela Dam site area on the Indus was made by Calkins and M. Ahmad during 1968. M.A. Latif in 1968 conducted geological work in southeast Hazara, produced a detailed geological map and reported the occurrence of phosphate mineralization. Geology of iron bearing oolitic beds in Langrial area was reported by Aftab Ahmad Khan, geologist of P.I.D.C. in 1965. Geology of Kohistan and adjoining Eurasian and Indo-Pak Plates was described by R. A. Khan Tahir Kheli (1979). Qasim Jan 1977 presented detailed petrography of granulites and garnet free ultramafic rocks of Jijal complex in Kohistan.

In the field of mineral exploration, the first prospect level exploration work was done by the formerly Mineral Directorate of Sarhad Development Authority (SDA), now "Exploration Promotion Division" of the DGMM. The work of SDA was confined to the following mineral deposits:

1.4.1 Hazara Phosphate Deposits

These deposits are located in Lagarban, Galdanian and Tarnawai, situated 15 km to the north east of Abbottabad. Extensive exploration, development and exploitation activities, with collaboration of British Mining Company of United Kingdom, have been conducted. These activities included surface and subsurface exploration through trenches, aditing and core drilling. As a result, more than 10 million tonnes of phosphate ore has been estimated in the region. (Note: All tonnage and grade figures are presented in this report as "exploration information" only).

1.4.2 Besham Lead Zinc Deposits

These deposits are located in the vicinities of Lahor and Pazang on both sides of Indus River toward north and east of Besham. These are found in Fault zone in highly tectonised region on the northern margin of Indian mass close to the MMT. The ore occurs in veins and as dissemination in the Proterozoic Pazang formation i.e. meta-volcanic (part of Besham basement complex). These resources were subjected to detailed exploration by SDA through surface and subsurface exploration including geological mapping, trenching, sampling, geophysical survey, aditing and core drilling that established about 3 million tonnes of Pb – Zn ore in the area.

1.4.3 Oghee Scheelite

This Tungsten mineralization is associated with pegmatites and aplites traversing the Precambrian Susalgali granite. SDA has explored the mineralization through surface exploration but so far, the commercial viability has not been established.

1.4.4 Monda Kucha Silica Sand

Good quality Silica Sand deposit, to the tune of about 70 million tonne, has been identified by SDA in Munda Kutcha area of district Mansehra in quartzose sandstone and quartzite of Abbottabad formation. The area warrants further study to prove required grade deposits for glass industry.

1.4.5 Barite Deposits

SDA conducted exploration work through a project named “Geological Survey and Investigation of Mineral Bearing Areas (GSIMBA)” on Barite deposits at Chando Maira and other areas aroundHavelian. As a result, about 0.25 million tonne deposits were established. Barite mineralization is also found close toLahor Lead-Zinc site at Besham

1.4.6 Langrial Iron Deposits

These deposits are hosted by the meta- sedimentary rocks of Abbottabad formation. These sedimentary iron deposits extend for several kilometers from Langrial village Abbottabad district up to Kalabagh with an average thickness of 1.5 meter (from 1 centimeter to 3 meter). These prospects were also explored by SDA through geological mapping, surface trenching and sampling. The samples show a grade of 32 to 48 % Fe. The tonnage has been estimated at 42.16 million tonne.

1.4.7 Jigal chromite Deposits

Alpine type Chromite deposits occur in the suture zone along the northwestern and western margin of Indo-Pak Plate. Chromite is found as pods, lenses, disseminations, layers and irregular shaped bodies in dunite and harzburgite rocks of Jijal complex. The main localities are Manidara and Shunkial. These deposits were subjected to detailed exploration through trenching, aditing, sampling and mapping, and as a result, viable sites for mining of chromite deposits have been established. Mining and sale of chromite is currently on going in the area through about 60 mines.

1.4.8 Manganese Deposits

Manganese deposits have been reported at Kakul and Galdanian in Abbottabad district and at Chorgali in district Mansehra. The ferruginous manganese occurs as lenses in the red bed of Galdanian formation overlying Abbottabad dolomite. A total of 55 lenses have been studied in the above localities and the preliminary estimates indicate a total of 140,000 tonne with average grade of 16% Mn.

1.4.9 Precious Stones

Gem quality peridot is found in dunite in upper Kaghan valley at Spat locality of district Mansehra. Abrasive and gem corundum deposits in meta- sediments are also located in Kaghan valley along with Beryl in the vicinities of Rajinwary and Giddarpur, district Mansehra. These precious stones are being extensively mined out by the locals through application of very primitive mining techniques, thus badly damaging the fragile gemstones. Gemstone prospects of Hazara warrant systematic exploration and exploitation on modern geoscientific lines.

1.4.10 Gold and Base Metals

Systematic geochemical exploration coverage of the region was initiated by SDA on the pattern of AIDAB Australia-Pakistan Gold Exploration and Mineral Analysis Project (GEMAP). Because of this survey various gold and base metals geochemical targets have been identified in Hazara division. In addition to above prospects, different private parties are involved in prospecting and mining activities of the following mineral commodities.

1.4.11 Soapstone Deposits

These deposits are found in different localities of district Abbottabad, Mansehra and Kohistan. Soapstone is being mined by private parties, particularly in the Sherwan area of District Abbottabad. The soapstone deposits of Sherwan occur as lenses, pockets and veins in the dolomitic rocks of Abbottabad formation. This stratiform soapstone occurrence has undergone folding, with evident thickening of soapstone in the crests and troughs of folds while thinning in the fold limbs (F. Siddiqui, personal observation 2014).

1.4.12 Manganese Deposits

The magnesite deposits of Sherwan were extensively explored and mined by PIDC in the past. At present the same deposits are leased out to different private companies for mining.

1.4.13 Coal Deposits of Harnwai

These deposits are located close to Abbottabad city in the area of Harnwai (Kala-meti) on Abbottabad-Nathiagali road. At present, some five coal mines are in operation of which the total monthly production is about 2000 tonne.

Apart from these, private local parties are also involved in exploitation of iron deposits of Langrial (Havelian), Lead-Barite deposits of Haripur, coal-graphite deposits in district Abbottabad and Mansehra, and quartz/feldspar deposits in different localities of Hazara division. Considerable mining activities for dimension stone namely Dolerite, (Trade name - black granite) are in operation in Oghi area of district Mansehra. Details of exploration and known mineralization are covered from page 21 onwards.

2. Geographical Environments

2.1 Geotectonic/Geodynamic Setting

The northern area of Khyber Pakhtunkhwa is a typical mountainous region representing the Himalayan ranges. Geologically, the region may be divided into three major tectonic units, namely, Eurasian Mass, Kohistan Island arc, and the Indian Mass. The Indian Mass and Kohistan Island Arc partly occupy the Hazara division.

2.1.1 Kohistan Island Arc

This is an island arc assemblage comprising intra-oceanic thoeliitic to calc-alkaline volcanic rocks and associated sediments, intruded by granitoid bodies and late subduction related intermediate to basic and subsequent acid granitoid and volcanic rocks.

The Kohistan island arc is separated from the Eurasian plate to the north by the Main Karakoram Thrust (MKT) and from the Indian Mass to the south by the Main Mantle Thrust or MMT.

This E-W oriented block is wedged between the northern promontory of the Indo - Pakistan crustal plate and the Karakorum block. Gravity data modeling indicates that MMT and MKT dip northward at 35 to 50 degrees and that the Kohistan arc terrain is 8-10 km thick (Malinconico 1989). Seismological data suggest that the Arc is underlain by Indian crustal plate. The northern and western part of the arc along MKT is covered by late Cretaceous to Paleocene volcanic and sedimentary rocks. This sequence is composed of several formations. The central part of arc terrain is mainly composed of Kohistan Batholiths which comprise an early (110-85Ma) suite of gabbros and diorites followed by more extensive intrusions of gabbros, diorites and granodiorite (85-40 Ma). The southern part of Kohistan arc is composed of a thick sequence of mafic and ultramafic rocks. The rocks of Kohistan Magmatic Arc in Hazara division may be divided into the following four tectono- metamorphic units from north to south:

- The Chilas complex
- Kamila Amphibolites
- Jijal Ultramafic Complex
- Main Mantle Thrust

The Chilas Complex: It forms the northern and upper unit of Kohistan island arc in Hazara division. It comprises of the layered norites and gabbros, metamorphosed to granulite facies. It is characterized by a series of south verging folds. It has been thrust south ward over the Kamila amphibolites.

Kamila Amphibolites: Consist of amphibolites, meta-gabbros and orthogneiss. This sequence comprises of highly tectonised sheared zones. Southward it is thrust over Jijal complex.

Jijal Ultramafic Complex: It forms a tectonic wedge between Kamila shear zone and the MMT. The Jijal complex is largely comprised of garnet–pyroxene-granulites and ultra-mafic rocks.

Main Mantle Thrust: A suture zone of ophiolite belts with various mélanges and blue schists.

2.1.2 Indian Mass

The Indian Mass is comprised of the Precambrian crystalline basement and a meta-sedimentary cover sequence. It consists of igneous and sedimentary rocks of different ages that are metamorphosed to various degrees and intruded by mafic to silicic sills, dykes and stocks.

The main tectono-stratigraphic units of the Indian Mass in Hazara division from north to south are described below.

Himalyan Crystalline Nappe and Thrust Belt

This 100 km wide, intensely tectonised zone, forms the north western margin of Indo - Pakistan crustal plate, and lies between the Khairabad - Panjal thrust faults and the Indus Suture Zone or MMT. It extends westward from Nanga-Parbat - Haramosh Massif up to Sarobi fault in Afghanistan, a distance of over 450 km. Its southern part is largely covered by Quaternary deposits of Haripur and Peshawar basin. North of Khairabad - Panjal fault, this basin is surrounded by low hill ranges comprised of Precambrian meta-sediments and a near complete sequence of fossiliferous Paleozoic and early Mesozoic rocks. In the southern part, this sedimentary sequence has been affected by low grade metamorphism. Northward, near the Indus suture zone, the tectono-stratigraphic setting changes from an essentially sedimentary fold and thrust belt to a metamorphic and magmatic terrain which is characterized by a thick stack of nappes, thrust sheets and mylonitised shear zones. In this complex fold and thrust belt three major structural zones are evident. From north to south these include:

I. The Crystalline Nappe Zone

II. The Khyber-Hazara Meta - Sedimentary Fold and Thrust Belt

III. The Peshawar Basin

The first two structural features lie in Hazara division, as described below:

I. Zone of Crystalline Nappe

This zone comprises the northwestern margin of the Indo-Pak Plate and forms a relatively narrow belt south of MMT. It extends westward from the Nanga Parbat – Haramosh Massif and continues up to Afghan border. It is composed of a thick sequence of Proterozoic basement gneisses and schists unconformably overlain by variably metamorphosed cover sediments. Subduction of Indo-Pak Plate has decoupled the sedimentary cover from the basement. The cover has been imbricated with an extensive series of thrust slices and crustal nappes. In Hazara, thrust structure has developed a large duplex with its floor at Mansehra Thrust and roof at MMT. Collision and subduction have thickened the Indo-Pak Plate margin through formation of a thick sequence of ductile mylonite, and imbrications of cover and basement along north dipping crustal-scale thrust stacks. The latter are comprised of a number of lithologically distinct nappes, which form a 5km thick tectono-stratigraphic sequence. Six major thrust nappes have been identified in this region. West to east, the south verging zones of thrust nappes are arranged in row and are separated by prominent sheared zones and thrust faults. These structural zones are:

- Mohmand-Swat Region
- Besham Nappe
- Hazara Nappe
- Banna Nappe
- Kaghan Nappe
- Nanga-Parbat-Haramosh Massif

- The Hazara, Banna and Kaghan nappes are lying in Hazara division.

II. Khyber Lower Hazara Meta Sedimentary Fold and Thrust Belt

This belt lies to the north of Khyber-Panjal Thrust and extends from Khyber Pass region to Garhi Habibullah. Peshawar basin is largely composed of this belt. To the northeast along Hazara-Kashmir syntaxis, this belt is wedged between the Panjal Thrust and Balakot shear zone. Possibly an extension of the Balakot shear zone, separates the Khyber-Hazara meta-sedimentary belt from the Hazara crystalline Nappes. Further to the west, the northern margin of this meta-sedimentary belt extends up to Besham and Swat crystalline Nappe. The Khyber Hazara Meta sedimentary belt is largely composed of slates and phyllites of Precambrian to early Mesozoic age. The Precambrian sequence is mainly composed of slates and phyllites with subordinate quartzite and marble, which crops out in southern part of the belt. The Precambrian section is largely in the form of thrust blocks with variation in metamorphic grade at some places in the eastern part of the belt (Hazara region). The Precambrian sequence is composed of (a) quartz schist, marble and quartzo - felspathic gneiss overlain by (b) thick widespread slate and phyllite and slightly metamorphosed greywacke sandstone (Hazara Formation). This sequence is unconformably overlain by quartzite and argillite (Tanawal formation).

III. Hazara Kashmir Syntaxis

The same geological features/structures found in India and Kashmir extend to Hazara where the structures abruptly turn back upon themselves to form a tight loop or reentrant known as Hazara syntaxis. It is a complex tectonic zone. No exact outlet is defined, though its axial zone is well defined by stack of thrust faults, which form a roof around its axis. The two major thrust faults are the Panjal fault and the lower Murree fault. Precambrian to Neogene sedimentary, volcanic and metamorphic rocks and Cambrian or earlier granitic rocks are exposed in the syntaxial zone and its vicinity. The axial zone of this syntaxis is largely covered by Murree Formation. North of Balakot, the axis of Hazara Kashmir syntaxis bends northeast ward and continues into Kaghan and beyond, into the Nanga Parbat - Haramosh region, where some workers call it ”the Nanga-Parbat Syntaxis”. Based on the two major faults, the structure of the area can be subdivided into:

- The tectonic element above the Panjal fault
- The tectonic element lying between the Panjal and Murree Fault
- The tectonic element below the Murree fault

IV. Main Boundary Thrust

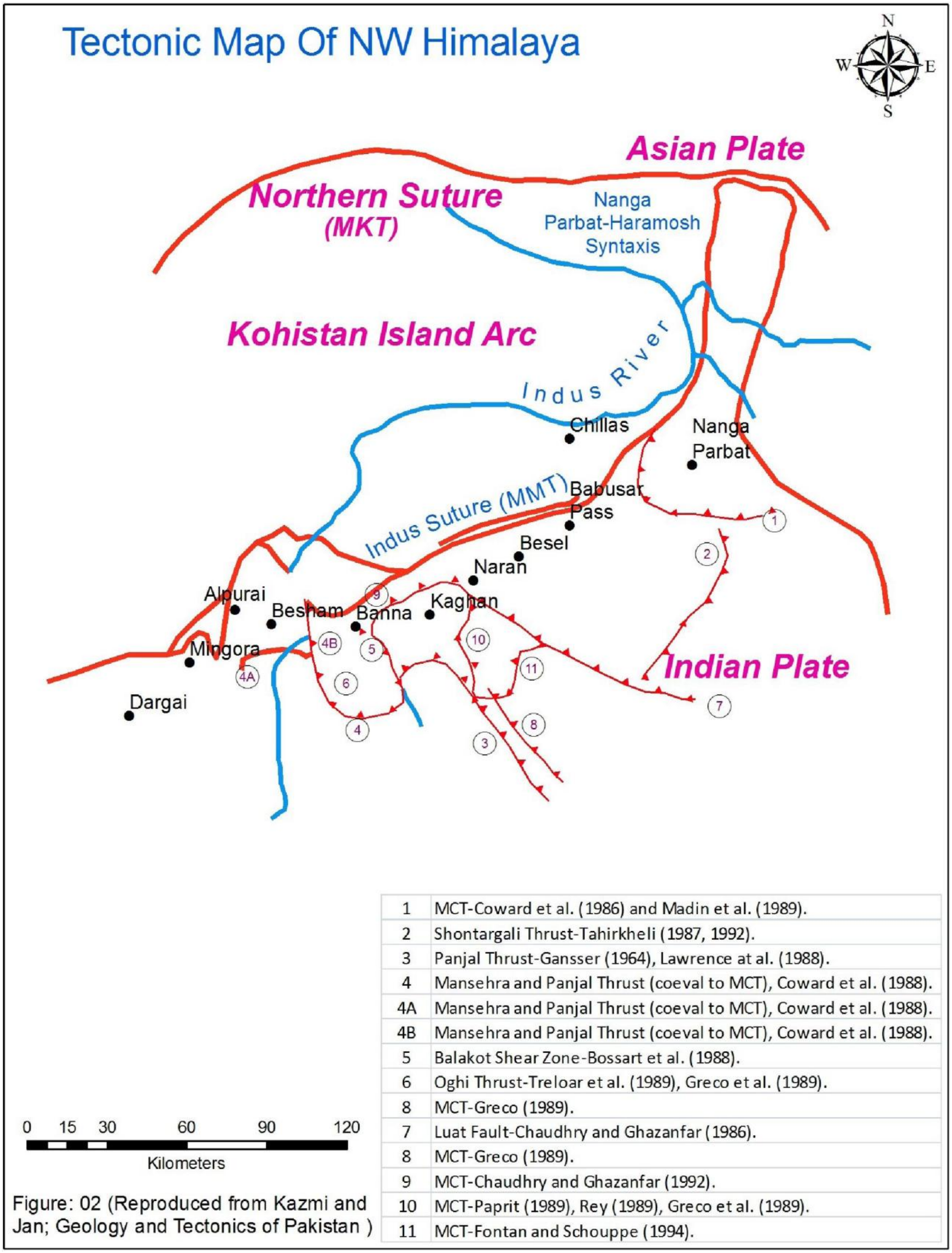
A hairpin shaped system of faults truncates the Murree formation on the east, north and west. West and north of this fault zone, within a short distance of 1 to 5 km, there is parallel thrust fault along which Precambrian sequence has been pushed over the Paleozoic and Mesozoic rocks. These two faults were named as Murree and Panjal thrusts. Some workers call the Murree Thrust on both limbs of syntaxis as the Main Boundary Thrust. This fault continues Northwestward near the apex of the syntaxis, and then bends southwards toward Balakot. The Murree fault runs in east–west direction south of Margalla hills. Westward, apparently, it links with Parachinar fault. Most the present workers now refer to the Murree-Parachinar fault as Main Boundary Thrust.

V. Panjral Thrust (Khairabad Fault)

It runs parallel to MBT on the eastern limb of syntaxis. The two faults curve around the apex of the syntaxis and then bend southward. These two faults join at about one km north of Balakot. However according to Baig and Lawrence (1987) a separate left-lateral strike slip fault truncates the Panjal fault and MBT north of Balakot. The Panjal fault probably separates from MBT about 6 km south of Balakot and continues beneath Kunhar valley alluvium up to Garhi Habibullah.

VI. Main Central Thrust

Main central thrust is an intracontinental thrust that separates the high and lesser Himalayas. It was first described by Heim and Gansser (1939) as tectonic contact between the Himalayan sedimentary sequence and the overlying crystalline complex. It has been traced from Nepal up to southern Kashmir (Gansser 1964) but opinions differ on the extension of MCT west of the syntaxis. Some of the earlier workers (Gansser 1964, Yeats and Lawrence 1984) extend MCT in to Panjal Thrust. Chaudry et al (1986) have shown that in Kaghan area the granites and gneisses of Sharda Group have been thrust southwards over the metasedimentary Kaghan Group. According to them the Luat-Batal Fault that separates these two groups is the MCT. Chaudry & Ghazanfar (1992) extend this fault westward up to MMT. Coward et al (1988b) suggested that Mansehra and Panjal Thrusts were the equivalent of the MCT separating the internal and external units of the Indo-Pak Plate. According to Greco (1991), the MCT joins a prominent granite-derived mylonite zone called the Balakot shear zone east of Mahandri. Balakot shear zone is 1 to 5 km wide zone of ductile deformation comprising of mylonites with alteration of dark mica-rich layers, Greco et al (1989). Balakot Shear Zone links up with Oghi Shear Zone in Hazara.



1	MCT-Coward et al. (1986) and Madin et al. (1989).
2	Shontargali Thrust-Tahirkheli (1987, 1992).
3	Panjal Thrust-Gansser (1964), Lawrence at al. (1988).
4	Mansehra and Panjal Thrust (coeval to MCT), Coward et al. (1988).
4A	Mansehra and Panjal Thrust (coeval to MCT), Coward et al. (1988).
4B	Mansehra and Panjal Thrust (coeval to MCT), Coward et al. (1988).
5	Balakot Shear Zone-Bossart et al. (1988).
6	Oghi Thrust-Treloar et al. (1989), Greco et al. (1989).
8	MCT-Greco (1989).
7	Luat Fault-Chaudhry and Ghazanfar (1986).
8	MCT-Greco (1989).
9	MCT-Chaudhry and Ghazanfar (1992).
10	MCT-Paprit (1989), Rey (1989), Greco et al. (1989).
11	MCT-Fontan and Schouppe (1994).

Figure 2 Tectonic Map of NW Himalaya

3. Geological Setting (Stratigraphy)

3.1 Kohistan Island Arc

Bard (1982a, b) presented a comprehensive model for the thermo-tectonic evolution of Kohistan arc and showed several broad zones of metamorphism from green schist to amphibolite facies. He contended that Kohistan underwent two major phases of tectono - metamorphic events, D1 and D2. Kohistan collided with Karakorum plate some 85 Ma ago and with north western margin of Indo-Pak Plate in Early-Paleocene (Trelaor, 1989 and Klootwijik 1992). Structural and geo - chronological studies indicate that much of the deformation in Kohistan predated collision of Kohistan with Indo-Pak Plate and is a combination of shearing and folding probably related to both suturing and subduction processes.

A brief account of metamorphism and deformation in Hazara division from north to south is presented below.

3.1.1 The Chilas Complex

These are basic to intermediate in composition and were probably in their environment as remobilized crystalline material capable of plastic flow. The remobilization was rather in cooler temperature; as a result they do not produce metamorphism higher than the amphibolite grade. These rocks constitute up to 37 km broad belt extending from Nanga Parbat to south central Dir. Most of the rocks along this belt are represented by felspathic norites essentially composed of plagioclase, ortho and clino-pyroxene with small amount of quartz, opaque minerals, biotite, hornblende and apatite. The amount of quartz increases in the intermediate members which may also contain K-feldspar. The rocks are layered/banded, many of the layers being noritic but some are anorthositic or pyroxenitic for long distance along the general trend of the bedding. These characteristics indicate that these are of igneous origin. Most of these rocks are gneissose and dioritic in nature. Garnet amphibolites are the rocks containing garnet as major constituent. Mineral segregation and quantity of garnet decreases north and south ward.

3.1.2 Kamila Amphibolite

These amphibolites form a belt, more than 300 km long and 45 km wide, extending from Afghanistan through Bajawar, Dir, Swat, Indus valley, Babusar up to Nanga Parbat. Amphibolites are also found in granulites belt and make up to 25% of that belt. The amphibolites can be grouped into two categories:

- Amphibolites of the pyroxenite belt
- Amphibolites of the southern belt

Amphibolites of the Pyroxenite Granulites Belt: These are small to large masses and form over fourth of the belt. Both types of rocks as mentioned above are similar in chemistry and they are recrystalized norites at same temperature and pressure and at the same time. The availability of water plays a major role in producing hornblende instead of pyroxene. The amphibolites, abundant along the southern margin of granulite belts, are the retrograde products of the granulites. The retrograde amphibolites belong to amphibolite facies, and some are represented by green schist facies.

Amphibolites of the southern belt: This belt consists mostly of amphibolites with some other rock types occurring locally. These are generally medium grained, but fine or coarse grained varieties are also present. These are well foliated, homogenous or banded. The amphibolites of this belt are further divided into:

- Banded Amphibolites of Sedimentary origin
- Coarse Grained Dioritic (Igneous) Rocks

Banded Amphibolites of Sedimentary Origin: It occupies about 25 % of the belt. The banded behavior of these rocks is due to variation in the proportion of amphibole and plagioclase-quartz in alternate layers. In some cases quartz, epidote or garnet rich bands also occur. The bands range from a few centimeters to over half a meter in thickness. The banded amphibolites vary in thickness from a few meters to hundreds of meter and may extend for 10 kilometers. Quartzitic bands, thick to medium bands of biotitic plus garnet gneisses and a few meter thick calcareous horizons are associated with the amphibolites.

Coarse Grained Dioritic Igneous Rocks: These are basically amphibolites, medium to coarse grained and not banded. In places, they contain xenoliths of fine-grained amphibolites and locally cut across the banded amphibolites. Their outcrops are irregular in outline and may or may not extend for long distance along the general trend of the bedding. Most of these rocks are gneissose and dioritic. Garnet amphibolites are the rocks, which contain garnet as the major constituent. Mineral segregation and quantity of garnet decreases north and eastward.

3.1.3 Kohistan Complex

These rocks at most places are characterized by abundance of garnet and can be classified into those with essential plagioclase (basic to intermediate in chemistry) and those with little or no plagioclase (ultra basic to basic). The plagioclase free rocks are less abundant and found mostly in southern part of the garnet granulite and are essentially composed of two to three mafic minerals; some are represented by granite, hornblende rock and pyroxenite. The basic granulites resemble some volcanics. This shows that the entire range of the Jijal granulites represents a metamorphosed differentiated mass of norite with subordinate hypersthene quartz diorite, olivine gabbros, troctolite, olivine anorthosite and pyroxenite. These Jijal granulites have undergone metamorphism and deformation resulting in crystallization of high pressure garnet granulite, amphibole facies metamorphism, chloritization, epidotization and amphibolitization of locally large mass of rocks.

3.1.4 Jigal Complex

These are ultramafic bodies exposed for about 6 km on the western bank of Indus River in between Jijal and Dubair Qila and striking in North West direction. These ultrabasics extend to the east into Allai in the vicinity of Bari, Pashtokaley and Damdara. Other localities where these ultramafics are exposed are Babusar in the upper reaches of Kaghan in Hazara and in Chilas. The thickness of Jijal complex varies from 4500 m between Jijal and Patan to less than 200 m east of the Indus in Allai. The main rock types of the ultramafics are pyroxenite, peridotite and serpentinite

3.1.5 Southern Suture Zone

It is also called Main Mantle Thrust, and is 4-5 km wide zone of ophiolite and mélanges, separating Island arc in north from the Indian mass in the south.

3.2 Indian Mass

Stratigraphically, the Indo-Pak Plate in Hazara can be divided into three different structural blocks.

i. The axial area of Hazara-Kashmir Syntaxis inside the bend of Murree fault.

ii. The Garhi-Habibullah syncline between the Murree and Panjal faults on the western limb of the syntaxis.
iii. Western arc area west of the Panjal fault

The various formations exposed in Hazara are summarized below:

Hazara Formation: A large belt of 15 km width extends southward from the vicinity of Garhi Habibullah through Abbottabad and then westward to Tarbela. The belt is composed of black and brown slate, phyllites, shale, greywacke sandstone, limestone and black shale. The formation has been placed in Precambrian age.Salkhala Formation: This is the oldest formation in the Hazara region composed of metamorphic rocks. The formation has been placed in Precambrian age. It crops out around the apex of syntaxis, several km in thickness, and narrows down to only few hundred meters near Balakot. The formation consists largely of quartz schist, marble, graphitic schist and quartzo-felspathic gneiss.

Abbottabad Formation: Previously known as Kingriali Formation, comprising mainly of dolomite, quartzite, limestone and phosphorite with some shale, sandstone etc. It extends northeast from Sirban near Abbottabad to Garhi-Habibullah. Other areas where the formation is exposed is in between Sherwan and the Indus River, between Muzaffarabad and Balakot, the Munda kucha syncline and the apex area of syntaxis. Abbottabad formation is variable in thickness in various sections; 450 m in Sirban, 700 m in Sherwan-Kacchi, 500 m northeast of Muzaffarabad, and 150 meter thick along the eastern flank of Garhi-Habibullah. It has been placed in lower Cambrian age (Shah 1977).

Tanawal Formation: Overlies the Abbottabad formation sequence represented by oolitic and pisolitic hematitic rock with volcanic materials and dominantly pelitic rocks consisting of shale, siltstone and argillaceous limestone. Previously it was called Datta formation by Gardezi and Ghazanfar. These rocks were considered upper part of Abbottabad formation. The Hematite resembles volcanic materials hosting manganese ore at places in addition to hematite and is therefore of considerable economic importance which has been investigated in detail by PMDC and SDA at places. Tanawal formation is Cambrian in age.

Samanasuk Limestone: Clastic in nature, black to dark grey in color, thick bedded with cross bedding at places, exposed in Hazara, underlies Daulatmar peak and covering parts of the area between Abbottabad and Garhi-Habibullah. Due to tight folding the thickness varies greatly at different localities. It has unconformable contact with underlying Tanawal Formation and its upper contact with Chichali shale represents a sheared zone. It is Jurassic in age.

Chichali Formation and Lamshiwal Sandstone: Both the Chichali Formation and Lamshiwal sandstone are very thin in Hazara. The thickness of the Chichali formation ranges from a few meters to 90 meter, consisting mainly of soft thinly laminated highly organic black shale. Due to its friable nature. Its upper and lower contacts are sheared. The Lamshiwal sandstone is 3-5 meter thick in Hazara. It consists of rounded quartz grains and minor glauconite in black calcareous matrix. The Chichali Formation is upper Jurassic while the Lamshiwal sandstone is upper to lower Cretaceous.

Kwagarh Limestone: In Hazara it forms a belt of outcrops extending southward of Abbottabad.The limestone occupies the centre of south plunging synclinal structure which extends southward to Kakul. Excellent exposures are also seen on the high ridges north of Sattu and toward Galdanian. It is dark grey, clastic, cross-bedded and Cretaceous in age.

Kalachitta Group: In Hazara, it occupies two main parts. The first part is a continuous belt extending from a point three kilometer east of Muzaffarabad northwestward to Balakot and the second is close to Abbottabad. Rocks of this unit are also found in the trough of syncline in the Nathiagali area. The greater part of this formation consists of grey, poorly bedded generally nodular limestone and dark grey calcareous shales. At Muzaffarabad the basal unit of this group is marked by quartzose sandstone, high alumina blue grey shale and black carbonaceous shale (coal bearing). Some of the beds are bio-clastic, containing abundant Foraminifera fossils. The rocks of this group have been placed in Paleocene to Eocene age.

Murree Formation: In Hazara this formation is found in the axial zone of the Hazara Kashmir syntaxis. This formation extends for hundred of kilometer in the east west direction. Its thickness varies from place to place; the maximum thickness measured is about 2600 meter. The formation consists of red siltstone, shale, and thick bedded red mudstone, and subordinate green, grey and maroon fine to medium grained greywacke. The greywacke beds are in lenses form ranging from 30-90 meter and thickness varies from 0.5 to 1-3 meter. It is early to middle Miocene in age. The lower contact with Kalachitta group is gradational and the upper contact with Siwalik series is conformable.

Mansehra Granite: The three granitic bodies i.e. the non-foliated granite at Mansehra, the Susal gali foliated granite and Tourmaline bearing granite at Hakale are genetically related to each other and have been combined into one unit called the Mansehra granite. Its southern and eastern margin extends from Darban through Mansehra up to Garhi Habibullah area. In Hazara area the Mansehra granite is called the”gneissose granites”. Mansehra granite is generally foliated except around Mansehra, and its contact with adjacent rocks is gradational and concordant with foliation. At places, the contact is found sheared. The granite is light in color; medium to coarse grained and is characterized by large phenocrysts of twinned microcline, sometimes 60 mm long. The main constituent minerals are microcline, oligoclase and quartz with small amounts of biotite and muscovite.

Bir Volcanics: In Sherwan - Bir area of district Abbottabad, a volcanic body of about 300 meter long and 100 meter wide is found at the confluence of Mangal nala and Siran River near Seri Sheer Shah village. The body is lying in north south direction and seems to be extended below the meta-sedimentary rocks of Tanawal formation. The fine grained, greenish, hard and brittle volcanic rock is described as Andesite.

Mylonite Zone: It is a zone of highly ductile and strongly deformed rocks in the west of Balakot and forms very important structural and metamorphic discontinuity separating the underlying Salkhala unit from the overlying higher Himalayan crystalline unit. It is well exposed in Kaghan valley at Darseri, 4km south of Naran. The rocks are granitic, amphibolites and meta - sedimentary indicating the characteristic features of the mylonite. The rocks above this zone are of amphibolite facies while below are green schist facies. The Oghi thrust that divides the Tanawal unit from the crystalline rocks appears to be the tectonic equivalent of mylonite zone and therefore part of the Main Central Thrust. This main thrust outcrops at Thakot separating Thakot group of rocks from Tanawal group and associated Mansehra granite gneisses.

Higher Himalayan Crystalline Unit: The rocks between the mylonite zone in the south and the Indus suture zone in the north. This unit can be separated into main divisions known as basement and cover. Both have certain structural and metamorphic features in common because of having undergone the same deformational events and recystallization during Himalayan mountain building process. However, a number of distinguishing features have been retained. In Kaghan valley, the subdivision is well displayed in the Saifulmaluk synforms.

(**a)** **Basement**: Consists of two major components i.e. felspathic granitoid intruded in pelitic and calcareous meta-sediments with overall features similar to Salkhala unit with higher metamorphic grade. The whole structure isgreatly disturbed, and the individual marker layers cannot normally be traced over any long distance, although someof the features are due to tectonic deformation and magmatic disruption. Discordant but deformed basic dykes asdolerite and schistose garnet amphibolite sheets are abundant at places.

The second component of the basement is a group of garnet and albite bearing semi-pelitic meta –sediments, termed as Naran formation, well exposed about 4 km east of Naran at Chunla. The meta -sediments are intruded by amphibolite dykes. The basement rocks form a series of sheets piled one on top of the other forming recumbent folds. The basement gneisses form the high mountains making up the ridge south of Kaghan valley.

(b) Cover Sequence: The metamorphic rocks forming the cover are well exposed around the village Burwai andhence named Burwai formation. These are quite different from the meta -sediments of the basement. Thesuccession starts with thick widespread homogenous oligoclase and garnet bearing amphibolites representingmetamorphosed basic igneous rocks. The basal amphibolites are overlain by marbles and calcareous mica schist thatalso contains concordant and discordant sheets of amphibolites. In contrast with sediments of basement, the cover succession is extremely coherent and the individual units are regionally persistent and some can be traced widely throughout the region. Basic extrusives are very abundant and acid extrusive is rare in Burwai formation.

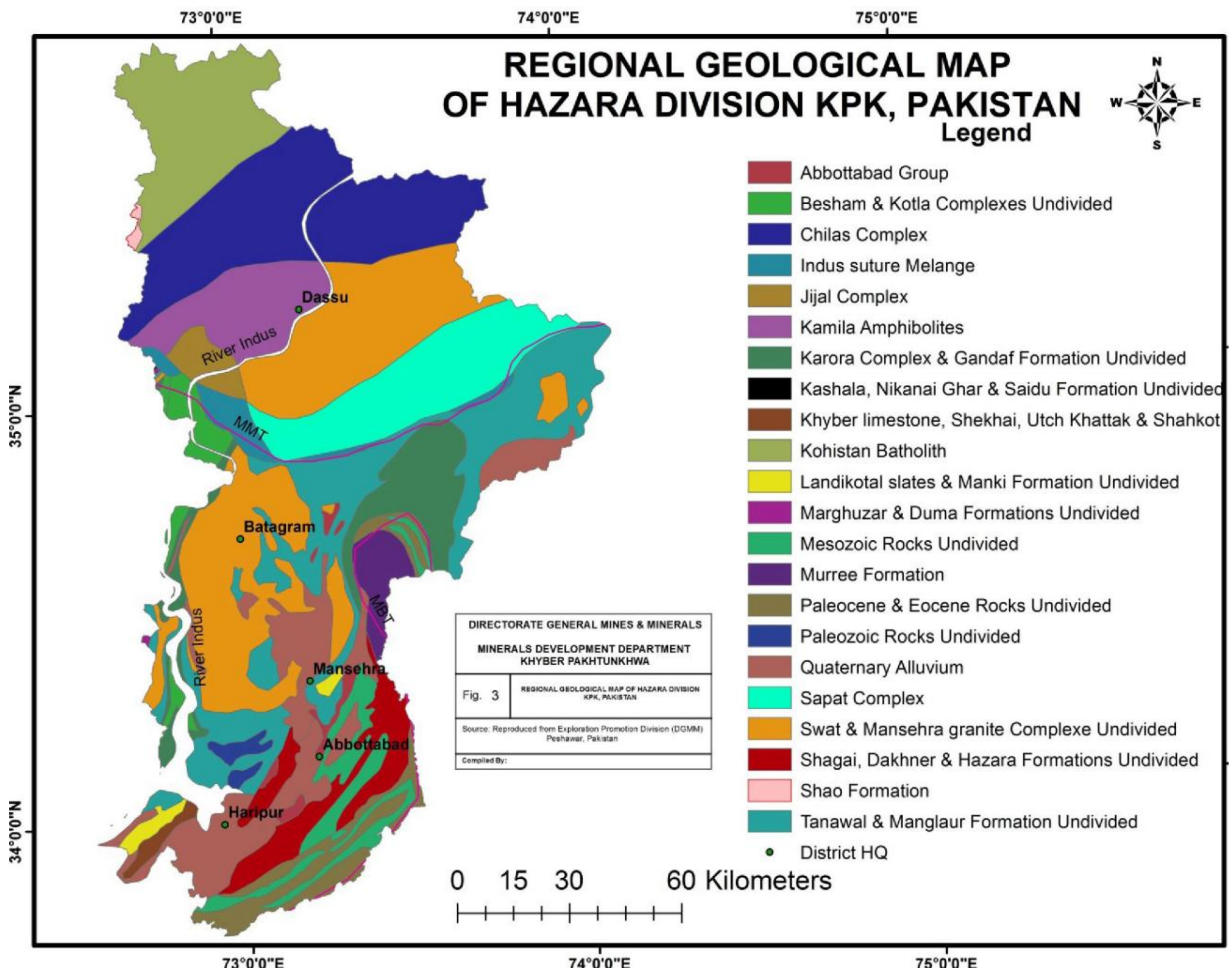


Figure 3 Regional Geological Map of Hazara Division, KPK

4. Metamorphism and Deformation

4.1 Kohistan Island Arc

Bard (1982a, b) presented a comprehensive model for the thermo-tectonic evolution of Kohistan arc and showed several broad zones of metamorphism from green schist to amphibolite facies. He contended that Kohistan underwent two major phases of tectono - metamorphic events, D1 and D2. Kohistan collided with Karakorum plate some 85 Ma ago and with northwestern margin of Indo-Pak Plate in Early-Paleocene (Trelaor, 1989 and Klootwijik 1992). Structural and geo - chronological studies indicate that much of the deformation in Kohistan predated collision of Kohistan with Indo-Pak Plate and is a combination of shearing and folding probably related to both suturing and subduction processes.

A brief account of metamorphism and deformation in Hazara division from north to south is presented below

4.1.1 The Chilas Complex

This huge complex consists of mafic to intermediate gabbro-norite with intrusion of small bodies of ultra-mafic -mafic to anorthosite association. These rocks have been intruded by dykes of hornblende.

-plagioclase pegmatites and of amphibolites which have caused local hydration of the host rocks to amphibolites. After placement, the complex underwent an essentially static low-p-granulite facies re-equilibrium. During this episode, the primary textures in gabbro-norite were recrystallized to polygonal granoblastic metamorphic fabric. Although the ultramafic association still retains original igneous textures and structures including excellent layering. The recrystallization was shortly followed by high temperature deformation; some rocks are gneissose or granulated with porphyroblastic feldspar and pyroxene showing straining (Jan 1979d). This apparently was followed by a phase of static hydration when pyroxene was partially replaced by amphibole under high temperature conditions. The principal deformation within the complex is confined to series of folds with northward vergence (antiform) and narrow shear zones of limited displacement. Some of these shears are ductile and hydration along these resulted in the formation of amphibolites with garnet, epidote, and scapolite accompanying hornblende. Others are low temperature shear zones with green schist facies assemblage (chlorite, actinolite, and epidote). These have grown during and after uplift. The amphibolite facies deformation and metamorphism are synchronous with the main deformation in the southern amphibolites belt. Emplacement ages of the complex have important implications:

- Chilas complex was emplaced soon after collision between Karakorum plate and Kohistan arc.
- The granulite facies re-equilibrium occurred quickly after emplacement.
- The amphibolites facies shears, which have been related to imbrications and south ward thrusting of the complex, followed this re-equilibrium quickly.
- Chilas complex may have provided thermal energy for the late Cretaceous regional metamorphism in Kohistan arc.

The emplacement of Chilas complex passed through a phase of granulite facies re-crystallization and weak deformation soon after emplacement but before its involvement in Kamila shear zone as elaborated below. There is sufficient heat associated with Chilas complex to derive widespread regional metamorphism and partial melting of the Kamila amphibolites.

4.1.2 Sothern Amphibolites Belt and the Kamila Shear Zone

The amphibolites belt is structurally complex with at least two phases of deformation (isoclinal folding and shearing) and metamorphism. The amphibolites belt and southern part of Chilas complex show a deep to mid crustal structure predating the Himalayan collision between the Indo-Pak Plate and Kohistan island arc. This structure was named the Kamila shear by Treloar et al (1990). Extending along the length of Kohistan, it narrows from 35 km in the Indus valley to 3.5 km to the south of Jal, Thak valley. The metamorphism of Chilas complex is transported southward across the shear zone in to stack of high-p rocks that have been assembled in the hanging wall of Tethyan subductin zone. The shear zone is constituted by array of mylonite zones. The intensity of shear zone decreases rapidly some 12 km north of Dassu. The shear fabric is ductile. The majority of shear criteria has south-to-south west verging thrust sense (Khan 1988, Treloar, 1990). Hydration along the shear has produced amphibolites facies assemblages. Post-dating this ductile shear is a series of low temperature shear zones developed during the exhumation of the rocks. Some of these contain green schist facies assemblages (chlorite, actinolite, and epidote) and others are represented by cataclasite and gouge filling. Some of these low temperature shear zones developed prior to collision between Kohistan arc and Indo-Pak Plate. Metamorphism and deformation within amphibolites belt seem to have occurred under amphibolite facies conditions, (Jan, 1988) with metamorphic grade showing an increase from the centre toward Chilas complex in the north and the Indus suture to the south. The Kamila shear zone shows an earlier ductile (high temperature) and a later brittle (low temperature) deformation. Shear zones represent southward thrusting of the arc over the Indo-Pak Plate. The southern part of the belt has been metamorphosed to a considerable depth. It has been suggested that some of the granitic rocks in the amphibolites belt are derived from partial melting of amphibolites.

4.1.3 Jigal Complex

It is 150-km^2 tectonic wedge occurring in the hanging wall of the Indus suture zone to the south of amphibolites. The northern half of the complex consists of garnet granulite and southern half of ultramafic rocks, both of which display good layering in some parts. Jan & Howie (1981), and Bard (1982b) suggested that high–p metamorphism occurred, and retrograde assemblages formed during uplift cooling. Ductile shears and thin veins contain garnet, hornblende and epidote. Low-grade (green schist facies) mineral assemblages (epidote, albite, chlorite, and actinolite) occur as alteration products in micro fractures and veins. Some granulites along the southern contact near Jijal are mylonitised with abundant growth of chlorite, and green blue amphibolites. Hornblendites make an important component of Jijal complex, commonly containing some garnet, rutile and in rare cases clinopyroxene. Felspathic rocks are associated with these rocks and it is tempting to think that the hornblendites are a product of hydration of the granulites during uplift. These rocks may represent the metamorphic base of thickened Kohistan arc. To sum up, there is strong likelihood that the pre-80 Ma deformation and metamorphism in Kohistan is related to over thrusting of Karakorum plate on Kohistan arc. It resulted in thickening of the crust, leading to high-p assemblages in the amphibolites belt

4.1.4 Indus Suture Zone

This zone consists of tectonic mélanges trapped between Kohistan arc and Indo-Pak Plate. These mélanges in Mohmand – Malakand, Mingora–Shangla and Allai area, consist of plutonic, volcanic and sedimentary rocks of Neotethys, together with some blocks from Kohistan and

Indo-Pak Plate. In the Babusar–Nanga Parbat area, the mélanges consist essentially of rocks belonging to Indo-Pak Plate and Kohistan arc with little oceanic materials. The Allai mélange zone in Hazara division consists of ultra-mafic rocks, meta-sediments, meta gabbros, green schists, phyllite and blue schist. A green schist facies overprinting at lower temperature affected the blue schists. In addition to local growth of garnet and calcic- amphibole, some rocks show extensive passage to green schist. The high - p metamorphism in the suture zone has been regarded by Jan (1991) as related to Cretaceous subduction. The Allai serpentinized peridotite contains talc, antigorite, and forsterite+iron oxide, formed from less forsteritic olivine. These rocks have suffered low to medium grade metamorphism (Arif and Jan 1993). Barbier et al (1994) have suggested that the assemblages and textures in the gabbroic rocks may be suggestive of green schist-epidote-amphibole facies sub-seafloor metamorphism. Much of the Indus suture mélanges formed during the Paleocene collision and obduction

4.2 Indo-Pak Plate

The Indo-Pak Plate has long and complicated thermo-tectonic history. A wide range of metamorphic assemblages, from sub green schist facies to granulite facies, formed mostly under medium pressure conditions, especially in northwest Himalayas. Field and petrographic studies, supported by some radiometric dates, suggest that the region has undergone several episodes of deformation and more than one cycle of regional metamorphism. The Indo-Pak Plate rocks to the south of MMT have been divided into internal and external (hinterland & foreland) sequence by Trelaor et al (1991). The external zone rocks occur to the south of Panjal – Khairabad Thrust and are un-metamorphosed and the internal zone rocks occurring to the north and in the hanging wall of Panjal–Khairabad fault are metamorphosed. Within crystalline internal zone, the Indo-Pak Plate can be divided into three litho-stratigraphic packages (Trelaor et al 1991). At the base is late Archean to Proterozoic basement complex of gneisses, calc-silicates and amphibolites. These basement rocks may have passed through more than one episode of deformation and high grade metamorphism before i) the deposition of late Precambrian and early Paleozoic sediments of Tanawal, Hazara and arenaceous to carbonaceous sediments of Abbottabad Formation, and ii) the intrusion of the Cambrian-Ordovician Mansehra granitoid. Baig et al (1989) suggested that these rocks underwent a Paleozoic low-grade metamorphism.

The Indo-Pak Plate rocks in northern Pakistan have passed at least three phases of deformation (Kazmi & Rana 1982). The first with possible synchronous metamorphism, may have accompanied the ophiolite emplacement above the Cretaceous–Paleocene boundary. The deformation accompanying the southwest thrusting of Kohistan onto India was characterized by ductile simple shear (S1) and incorporated D1 and D2 events of Coward et al (1982-88). The second major phase of deformation in the internal zone can be related to re-imbrications of metamorphic pile within the south verging crustal thrust stacks. These nappes are internally imbricated by ductile to brittle shear zone in which main phase of metamorphic fabrics are externally reworked. In such nappes metamorphic grade increases northward and structurally upward with sharp metamorphic break across the shears separating individual nappes. Despite the apparently upward increase in metamorphic grade, rocks in the immediate surrounding foot wall of the MMT are of lower grade (green schist facies) than those which underlies them structurally.

4.2.1 Metamorphism in Hazara

Large amount of data has been published on the stratigraphy, structure, deformation and metamorphism of this region. Treloar et al (1989a, b) and Baig (1990) showed that the Besham basement complex was separated from the adjacent Hazara and Swat areas by post metamorphic faults. The Besham basement displays a regional Early Proterozoic amphibolites facies metamorphism and only a low grade Paleocene (Himalayas) metamorphism, whereas the Hazara rocks show a regional Paleogene metamorphism. Dominant structures in this area are a section of N trending folds that die out or swing east or west along the southern margin of the area in conformity with the Khairabad thrust. The Himalayas metamorphism increases from south to north in Hazara. Rocks in northern margin of Peshawar basin are of low grade. Garnet occurs sporadically in between Jawar in Bunair and Darband in Hazara. The transition from green schist to amphibolites facies within Permian meta-volcanic rocks occurs in this region. Further north the rocks are amphibolites facies and garnet is wide spread. Metamorphic intensity from chlorite grade near Abbottabad reaches to Kyanite and Sillimanite grade in the north.

4.2.2 Metamorphism in Kaghan- Hazara Syntaxis

In this area a complete section of Indo-Pak Plate crust is exposed. In Hazara it comprises of Precambrian to Cambrian basement. The basement was presumably deformed and metamorphosed during pre Himalayan thermo-tectonic events. Chaudhry et al (1980, 81) reported a large number of metamorphic mineral assemblages developed from a wide range of rocks of igneous and sedimentary parentages. One highly unusual assemblage in schist from Babusar area consists of garnet- hornblende – chloritoid-chlorite-zoisite-phengite-calcite-quartz-plagioclase (Chamberlain et al 1991). The intensity of metamorphism increases up valley (northward) from very low grade in the core of syntaxis (Bossart, 1986) to high amphibolites and eclogite facies beyond Naran (Pogante & Spencer 1991). In accordance with classical subdivision of Himalayas, the syntaxial area can also be divided into three elements. Higher Himalayan crystalline nappe (HHC), lesser Himalayas and sub Himalayas. Each one of these is composed of one or more tectono - stratigraphic units. In general the thrust units become older towards the uppermost tectonic elements. The three elements are briefly described in the following paragraphs:

The deepest crustal level is represented by the HHC, with predominantly carbonatic phanerozoic cover. The HHC is placed over the lesser Himalayas detrital formations along MCT. Polyphase folding, schistosity and ductile shearing affect the nappe structure of the basement and cover rocks. The deformation style is very ductile at the base of HHC. The lesser and sub Himalayas packages are separated from each other by the MBT (locally named as Murree Fault). Both these packages are folded, internally imbricated, and in the case of lesser Himalayas, the cover may be detached from the basement.

The sub-Himalayas element, which consists of Murree Formation, is exposed in the core of syntaxis. These early Tertiary rocks have been little affected by metamorphism. Bossart (1986) suggested that the very low-grade metamorphism in the stratigraphy of the detrital sequence is due to sedimentary thickening. This means that the style of metamorphism here is entirely different from the one in the other two packages.

The lesser Himalayas consist of Salkhala unit & Panjal unit. Metamorphism in these units ranges from very low grade to upper green schist facies/epidote amphibolites facies (garnet zone). There is metamorphism transition from the amphibolites facies ductile deformation in the Hanging wall (HHC) of the MCT to green schist facies in the footwall of lesser Himalayas. The HHC occupies upper Kaghan and consists of basement granitic gneisses intruded into older paragneisses (The Sharda group of Chaudhry et al 1987) which has complex deformation history. Both the basement and the cover rocks have experienced Barrovian-type syn-to-post deformational metamorphism with peak condition suitable for partial melting. With a Sn-Nd age of 49 Ma (Tonarini et al. 1993), it can be concluded that by this time the Indo-Pak Plate cover in Kaghan was buried to depth of more than 50km beneath the Kohistan Arc.

Table 1 Regional Geological Setting of Hazara Division

TECTONO-STRATIGRAPHIC BELT	AGE	RELATED GRANITOIDS	TECTONIC BLOCK
Chilas complex	Late Permian to Triassic to Early Jurassic	Kohistan Batholith	Kohistan Island Arc
Kamila Amphibolites belt		Late intrusive	
Amphibolites Shear zone		Late intrusive	Kohistan Island Arc
Jijal complex	Mid Cretaceous to Tertiary	Lahor granite	
Main Mantle Thrust	Cretaceous	Lahor granite	
Himalayan Crystalline Belt	Precambrian to Paleozoic	Besham granitoid	Indian Mass
Lower Hazara meta sedimentary Fold & Thrust Belt	Precambrian to Paleozoic	Thakot granitoid, Oghi granite, Mansehra granite	Indian Mass
Hazara Kashmir Syntaxis		Besal granite, Naran granite	Indian Mass
Panjal Fault		Mansehra granite	Indian Mass
Main Boundary Thrust		Mansehra granite	Indian Mass

5. Known Metallic Mineralization

5.1 Kohistan Island Arc

The evolution of Kohistan Island Arc took place during mid to late Cretaceous period. The Island Arc welded to the Eurasian Plate and subsequently became the site of Andean type mineralization. As a result of subduction below the Indian and Eurasian Plate, igneous activities took place up till Eocene period. The known mineralizations within Kohistan Island arc in Hazara division are described below:

Jijal Chromite Deposits: Podiform, veins, lenses and disseminated chromite deposits are found in dunite and harzburgite rocks in Manidara and Shukial dara of Jijal, These deposits were extensively explored by SDA that established tens of thousands of tonne of chromite in the area. At present, the area is under active mining by many private companies. The grade of chromite ranges from 30 to 50% Cr_2O_3.

Kulai Au-Cu Mineralization (Patan Area): Structurally controlled copper mineralization in the form of malachite, bornite, chalcopyrite and cuprite, along with gold mineralization, is found in sheared zones upstream in Kulai khwar on the east side of Indus River.

Jalkot Copper Mineralization: Scattered copper mineralization in the form of malachite, azurite and chalcopyrite is found associated with quartz veins and shear zones in the Kamila amphibolites. The area is also anomalous in Au, Cu, Pb, Zn, Ni and Co in stream sediments samples. The area needs further exploration to identify viable metallic mineral deposits.

Platinum Group Minerals (Pt, Pd):have been identified in Jijal complex, and geologically investigated by Lake Resources, Australia under Exploration License.

Kandia Valley Copper Mineralization: Sporadic showing of copper mineralization is reported from Kandia valley, district Kohistan. The mineralization is in the form of malachite showings and blebs of chalcopyrite with quartz veins. The area is also anomalous for Au, Cu and Zn in geochemical stream sediment samples, and requires detailed exploration.

5.2 Indo-Pak Plate

The Precambrian crystalline sequences of the Indo-Pak Plate are situated between the Main Boundary Thrust (MBT) in the south and Main Mantle Thrust (MMT) in the north.

These crystalline rocks consist of sedimentary and a large number of igneous bodies of different composition and of different ages, which have been metamorphosed to varying degrees. Sills dykes and stocks, which are mafic to silicic in nature, have intruded the above rocks known mineralization in the Indo-Pak Plate crystalline rocks include-

5.2.1 Himalayan Crystalline Zone

Besham Lead-Zinc Mineralization: Lead-Zinc mineralization occurs on the northern margin of Indo-Pak Plate and is found in Lahor and Pazang localities within a 12 km linear belt, extending on both sides of the Indus River. The mineralization occurs in the metamorphosed and complexly deformed volcanic rocks. SDA reported about 3 million tonne ore with Pb ranging from 3.1 to 3.45 %, and Zn from 4.2 to 6.2% in both sites respectively. Besham Pyrrhotite Mineralization: Pyrrhotite mineralization within the carbonate rocks is running somewhat parallel to the lead - zinc mineralization.

Hal, Kohal Lead Mineralization: Galena bearing quartz veins (fracture filling) occur in Precambrian meta-sediments of Hazara formation. At Pashwal the veins also contain pyrite, sphalerite and chalcopyrite.

Rare-Earth Minerals: Occurrence of rare earth minerals has been reported in Mansehra granite.

Allai Magnetite & Galena Mineralization: Skarn type mineral deposits are found in Allai and surrounding areas as magnetite (in skarns, hornblendites and ultra-mafics), and Sphalerite / Galena (in skarns, veins and altered granites).

Lahor Molybdenite Mineralization: Molybdenum mineralization is found in silicified skarns, altered and silicified Lahor granite. The skarn type mineralization appears to be associated with the Precambrian Lahor granitic rocks. No viable mineral concentrations have been discovered so far in this area.

Besham Magnetite Deposits: These are associated with Lahor Granite and associated metamorphic and mixed rocks of the following types. The three types of skarns developed contain variable quantity of magnetite:

i. Magnetite-Carbonate skarns.

ii. Siliceous-Magnetite skarns.

iii. Magnetite-Silicate skarns

Ashraf (1980) reported an estimated 6.8 mt with metal contents of up to 40% Fe, 2% Zn, 2% Sn, 0.05% W and 0.1% Mo.

Oghi Scheelite Deposits: SDA has explored these deposits through sampling and geological mapping. Shams in 1995, also conducted preliminary geological investigation and reported 3.2 %W. The area has potential for Tungsten deposits and needs systematic follow up exploration.

5.3 Foreland Fold – Thrust Belt (NW Himalaya)

Iron deposits of Langrial, Galdanian and Abbottabad: Sedimentary iron ore exists in the Paleozoic sequence (Abbottabad group) as lenticular beds (30-50m thick) of massive hematite clay between sequence of dolomite and limestone (Jurassic) in Galdanian and Abbottabad.

Sedimentary iron ore of laterite, chamosite, hematite occurs along the unconformity between Paleozoic Lockhart limestone and Cretaceous Kawagarh Formation. The total deposit in all these sites is about 95 million tonne with iron contents of Fe 14-46% at Langrial, Fe, 20% at Galdanian and Fe, 9 – 50% at Abbottabad localities.

Faqir Mohammad Lead – Barite Deposits: Galena is found in quartz-barite veins in Eocene limestone Ahmad (1969).

Galdanian, Chura Gali Manganese Deposits: Manganese and iron bearing red bed formation occurs within Cambrian sequence of limestone, shale, sandstone, quartzite and dolomite (Abbottabad Formation). Mn ore occurs in thin, discontinuous lenses (2-7m). There are several lenses in the area. Mn-6.7% with Fe-20.4% is reported in Galdanian while Mn 7 to 22% with Fe-28% is reported from Chura Gali with 180,000 tonne estimated tonnage.

Haripur Lead Deposits: Pb is hosted in sandstone/quartzite and argillite of Tanawal formation. Mineralization is in the form of lodes occupying fissures/fractures. The mineralization is sporadically exposed as cluster zone extending to about 10 km from Alluli in south to the Hill village in north. S. Nayyer Ahsan, Ahmad Hussain and Waliullah of GSP, September, 2003 have established average grade of Pb 7 % based on the results of 17 samples.

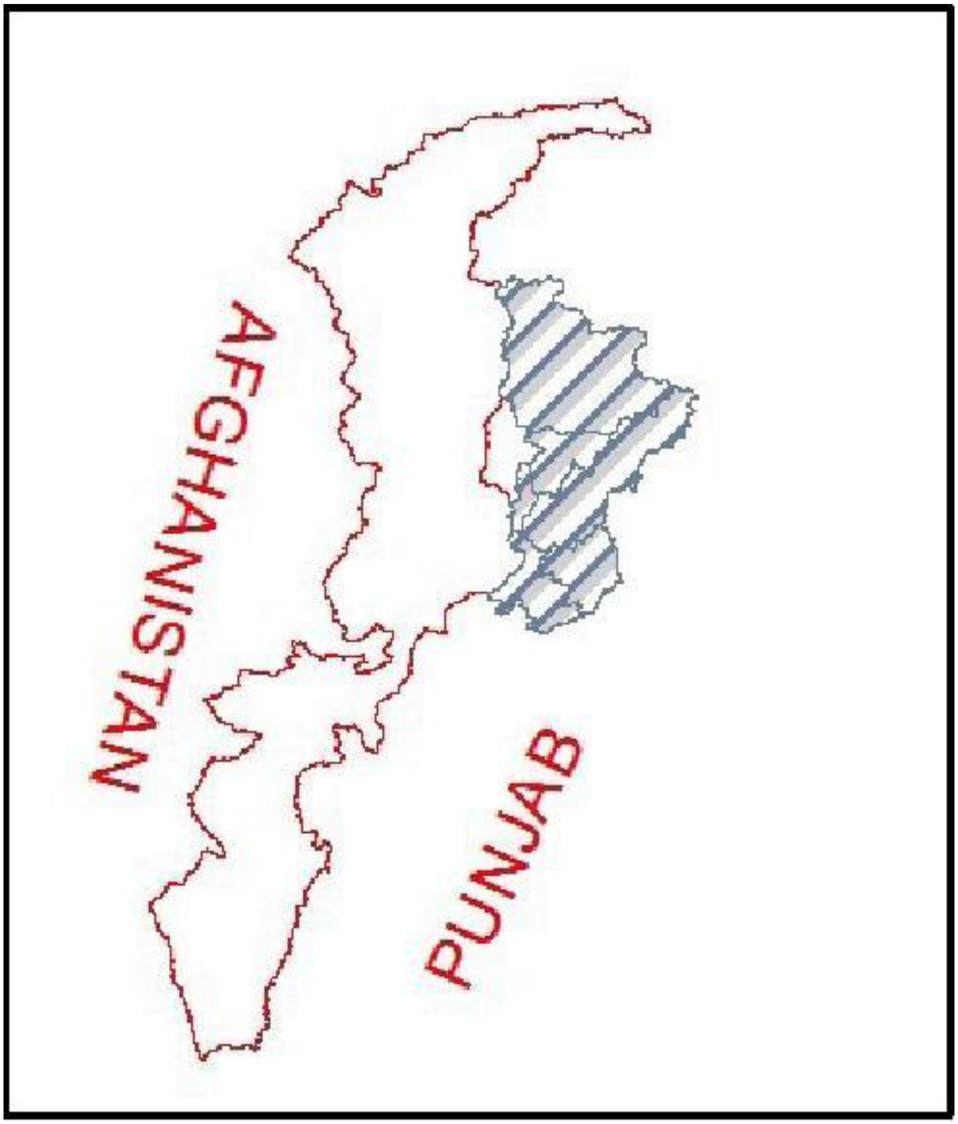


Figure 4 Mineral Location Map of Hazara Division

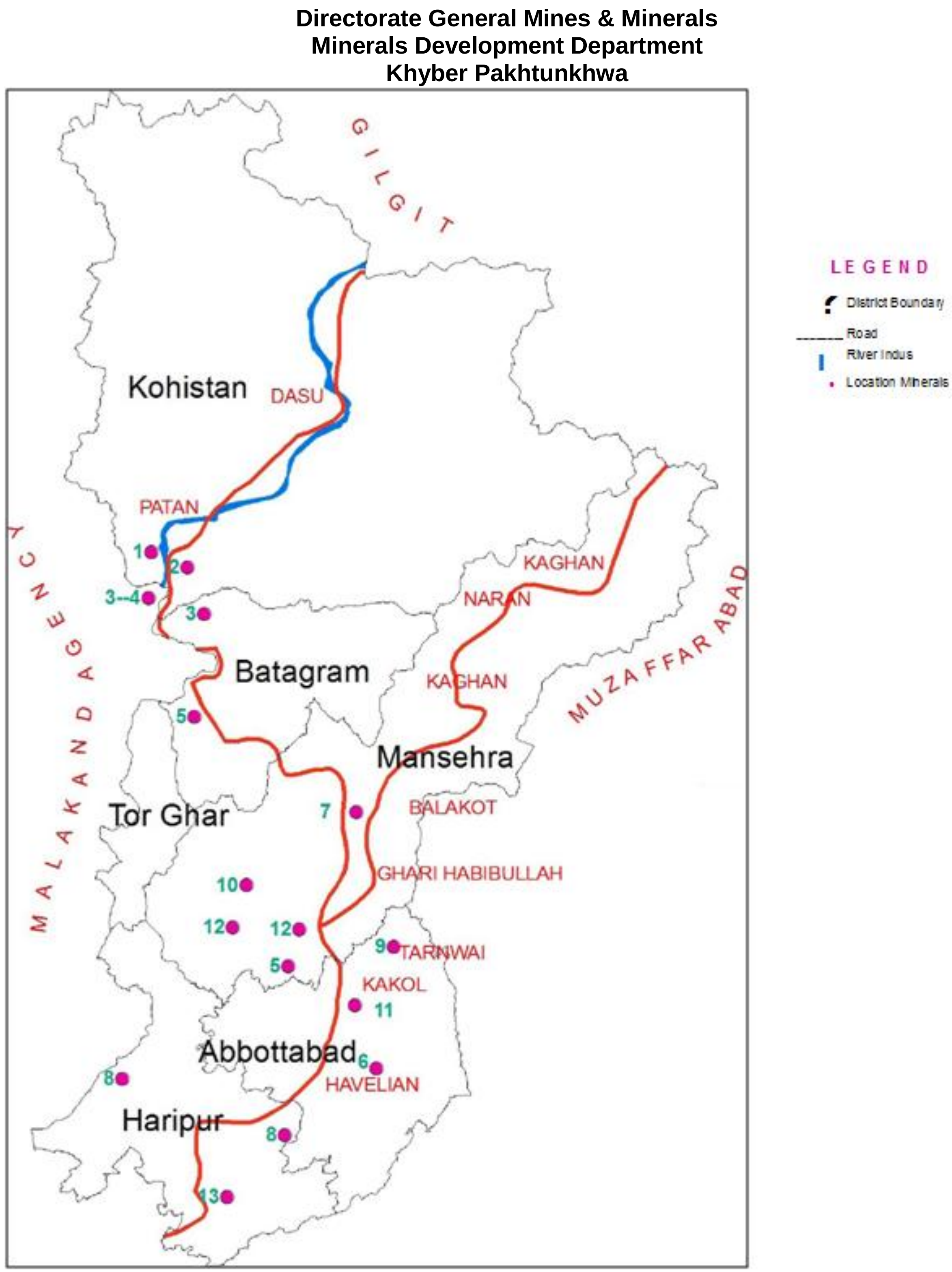


Figure 5 Mineral Location Map of Hazara Division
Source: Exploration Promotion Division, DGMM)

Table 2 Minerals and their Names

S.NO	Mineral	Mineral Name (Local)
1	CHROMITE	(Mani Dara)
2	COPPER-MAGNETITE (Kolai)	
3	LEAD-ZINC	(Pazang-Lahor)
4	BARITE	(Besham)
5	SOAPSTONE	(Sherwan)
6	BARITE	(Chando Maira)
7	SILICA SAND	(Munda Kucha)
8	IRON ORE	(Langrial)
9	MANGANESE	(Choora Gal)
10	SCHEELITE	(Oghi)
11	PHOSPHATE	(Kakul, Lagarban)
12	FELDSPAR	(Oghi)
13	RED OXIDE	(Gora Area)

6. Metallogeny

Geologically, Hazara division occupies a small portion of Kohistan island arc north of MMT (from Jijal to Basha dam site along KKH), and parts of northern margin of Indo-Pak Plate south of MMT (from Dubair nalla to Tarbela area). The expected mineralization in these geological environments is briefly indicated below.

6.1 Kohistan Island Arc

6.1.1 The Chilas Complex

The Chilas complex is 300 x 40 km layered plutonic mafic-ultramafic complex. One may expect the following ore deposit models in this complex.

Merensky Reef Type PGE: The known chromitites and dunite rocks of Chilas complex have potential for Platinum group elements. PGE are already reported in Chilas area, associated with ultra-basic rocks of Chilas complex (Ashraf and Hussain 1994).

Stillwater Type Massive Sulphides: The basic to intermediate rocks have potential for Stillwater type massive and disseminated Cu – Ni sulphides.

Bushveld Type Massive Deposits: The Chilas layered complex has also potential for Bushveld type Fe-Ti-V deposits. MINORCO geochemical results indicate anomalous concentration of Fe, Ti and V in basic to ultra-basic suites of rocks north of MMT.

Podiform Chromite: The ultra-basic rocks have potential for podiform chromite deposits. Chromite mineralizations, associated with dunite and harzburgite rocks, are reported from Chilas area.

MINORCO also reported geochemical anomalies of PGE, Ni and Cr in -80 # stream sediment samples to the north of MMT at Dassu and recommended the area for follow-up studies.

6.1.2 Kandia Volcanic Belt

Andesite and dacite volcanic rocks are exposed in the Kandia valley of district Patan. These volcanic rocks are possibly the eastern extension of Dir-Utror volcanics of Eocene age, and may have potential for the following ore deposits:

Porphyry Type Cu-Mo-Au Deposits: This type of mineralization occurs in sub-volcanic intrusive. Breccias and altered quartz veins host the copper and gold mineralization. Sporadic showings of malachite are reported from Kandia valley. The mineralization is in the form of malachite showings and blebs of chalcopyrite with quartz veins.

Epithermal Au-Cu Deposits: This type of mineralization is associated with geothermal system of volcanic centers and calc-alkaline volcanic sequences. Potential of this type of mineralization exists in the geothermal system of the volcanic rocks of Kandia valley. Geochemical stream sediment samples show significant Cu, Au and Pb anomalies in Kandia valley.

Structurally Controlled Mineralization: Structurally controlled and/or metamorphogenic Cu-Au-Pb and Zn mineralizations are generally associated with shear zones and fault systems in the Island arc environment. In district Dir (upper), copper mineralization is associated with local faults in volcanic rocks as isolated lenses. The same may also be expected in the volcanic rocks of Kandia valley.

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FIG. 5	SIMPLIFIED TECTONIC METALLOGENIC MODEL OF NORTHERN PAKISTAN
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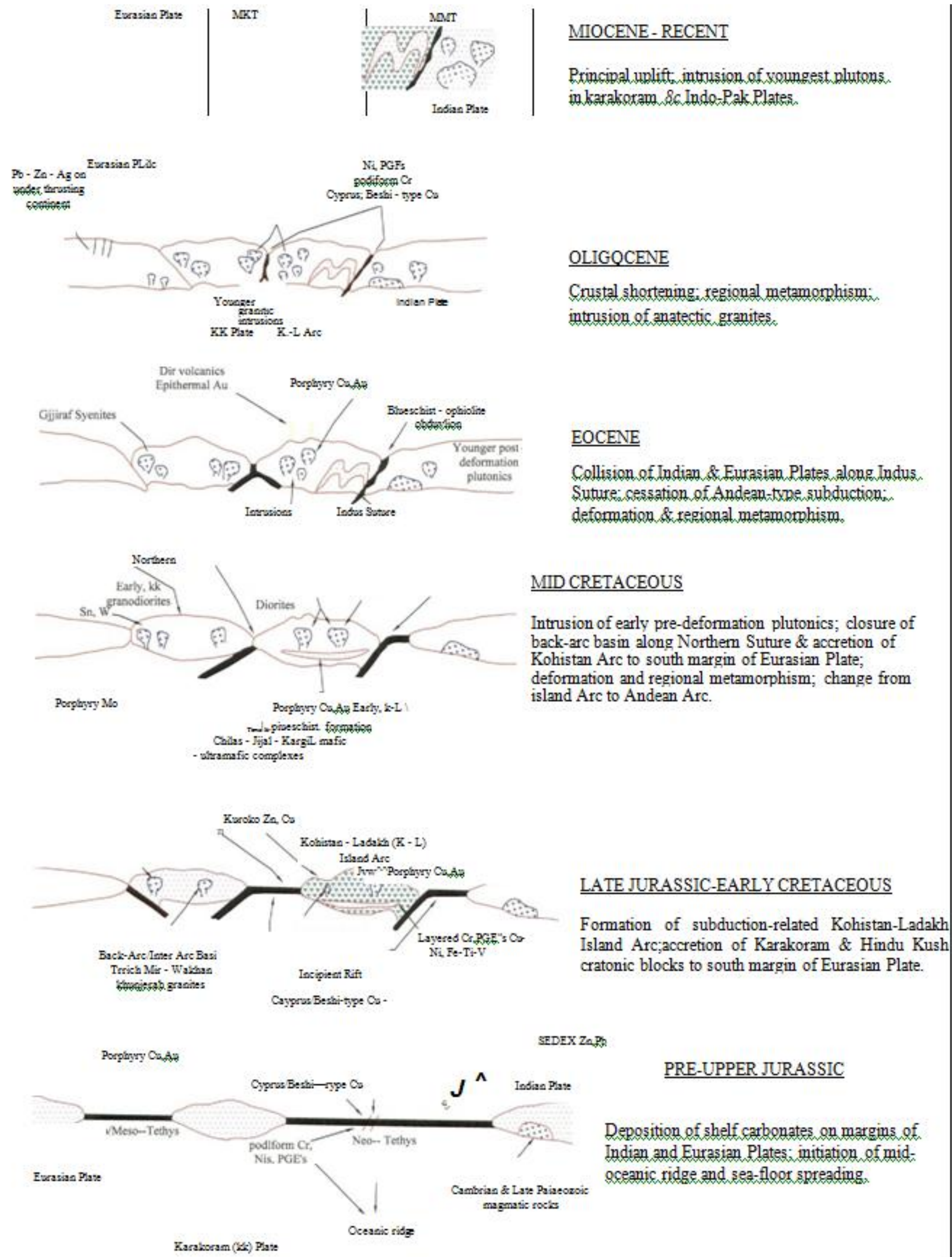


Figure 6Simplified Tectonic Metallogenic Model of Hazara

6.1.3 Kandia Volcanic Belt

This suite is calc – alkaline, derived from volcanic and plutonic rocks with minor sediments and small ultra-maific lenses. Lack of typical volcanics and ophiolites indicate absence of massive sulphides and other mineralization of island arc environment. However, one may expect the following types of ore deposits along this belt.

Structurally Controlled Deposits: Copper-gold mineralization may be associated with shear zones or local faults, probably related to late intrusion of diorite to granodiorite rocks in the amphibolites belt. For example, copper mineralization has been observed from the amphibolites and hornblendite rocks at Kotigram area of district Dir lower (M. Nawaz personal observation).

Podiform Chromite: The ultra-basic rock bodies intruded into the rock sequence of Kamila amphibolites belt may have potential for podiform or layered type chromite deposits.

Disseminated PGE & Ni Sulphides: The basic to ultra-basic rocks i.e. hornblendites; dunite and harzburgite may have potential for low-grade disseminated Ni and Platinum group elements mineralization. Ni mineralization is reported from the Tora - Tiga complex consisting of hornblendites with minor dunite, located in Gosum area about 10 km west of Timergara, district Lower Dir (M. Asif, 1990).

6.1.4 Jigal Ultra

The Jijal and Sapat ultramafic complexes, having Island Arc plutonic nature are located to the north of Southern Suture Zone in district Kohistan and Mansehra. These complexes may have potential for the ore deposits explained below:

Podiform Chromite: The dunite and harzburgite rocks have potential for podiform chromite deposits. Chromite deposits in lenses form are already reported and mined at Manidara (Jijal) and Sapat (Kaghan) localities.

Merensky Type PGE: Layered, disseminated and structurally controlled platinum groupelement concentrations (Pt & Pd) may be associated with mafic to ultramafic rocks of Jijal and Sapat complexes. Notable enrichment of gold and platinum group elements has already been reported from Jijal complex (D. Jay Miller, Robert R. Loucks & M. Ashraf, 1986 &1991).

Cyprus Type Massive Sulphide: The mafic and ultramafic rocks of Jijal and Sapat complexes may contain massive copper and gold deposits. Scattered showings of malachite, associated with basic to ultrabasic rocks are common in these complexes.

Structurally Controlled Deposits: Structurally controlled copper-gold mineralization has been found in Kuali Khwar located on the eastern side of River Indus. A copper value of 3% with 3 g/t gold has been recorded. (M. Nawaz personal observation)

Gemstone: The ultrabasic rocks of these complexes have gem quality peridot. In Sapat locality, of district Mansehra, gem quality peridot, associated with dunite rocks is already being mined, albeit with very primitive and wasteful methods.

6.1.5 Southern Suture Zone

Ophiolite rocks and metamorphosed mélanges occur along SSZ, including the Allai tectonic mélange (oceanic-island arc components) and Shangla mélange comprising of the oceanic trench and continental margin components.

The rock assemblages of ophiolite belts and tectonic mélanges have potential for:

Podiform Chromite: The ultrabasic rocks (dunite, serpentinite) have potential for podiform chromite deposits. Chromite deposits, in lenses form, are being mined in Shangla mélange and Allai mélange zones. More chromite deposits are expected along the Southern Suture Zone.

Metasomatic Deposits: Skarn type mineralization along mélange zones is common. In Allai mélange zone skarn of Cu, Pb, Zn, Ni and Fe is already reported. One may expect more skarn type mineralizations along Southern Suture Zone. Allai tectonic mélange (oceanic + Island Arc components) is located to the south of SSZ.

Cyprus Type of Massive Sulphide Deposits: The massive sulphide (Cu, Zn & Au) deposits occur in pillow basalts associated with ophiolites of oceanic ridge and back arc basins, Mn-Fe rich cherts are also found. FATA Development Authority has explored Cyprus type deposits in typical ophiolite mélange environment in BOYA /Shinkai area of North Waziristan Agency. One may expect the same within ophiolite and mélange zones along the SSZ.

Gemstone: The talc carbonate schists, with or without later quartz veining, may have potential for emerald deposits. Emeralds are found and being mined at Mingora of distinct Swat. The emerald mineralization is associated with talc carbonate schists of Mingora mélange zone. Emeralds are also reported and being mined in Shangla and Charbagh mélange zones. Therefore, one may also look for emerald mineralization in Allai mélange zone in Hazara division

6.1.6 Recent Igneous Belt (Late Tertiary)

These are intrusions of leuco-granite in Kohistan Island arc, and are crust melted. Volcanic structure (intrusive centre, ring structure, circular and rounded features) noted from satellite imageries are recommended for mineral prospecting based on satellite imageries interpretation.

6.2 Indo-Pak Plate

Indo-Pak Plate is comprised of Precambrian crystalline basement between Main Boundary Thrust and Kohistan Island arc. This basement consists of different igneous and sedimentary rocks of different ages and metamorphosed to varying degrees intruded by mafic to silicic sills, dykes and stocks. Known mineralization in the Indo-Pak Plate includes:

Broken Hill Type Pyrrhotite-Pb-Zn Mineralization

Shelf sediments along the northern margin of the Indian mass have potential for sedimentary exhalative lead-zinc deposits. The Pb-Zn deposits in Besham are the most relevant known example. The occurrences of similar deposits are expected in other areas along this belt. Some are reflected in the results from the drainage geochemical survey in Allai Kohistan, Oghi and Sharda group of rocks in Naran.

Mississippi Valley Type Massive Pb-Zn-Cu Deposits

The meta-sedimentary rocks at Khan Valley comprise of quartzite, schist, granite gneisses, carbonates, quartz mica schist, graphitic schist, pegmatites and Kaghan pelites (Kaghan Formation). This belt of rocks is separated on the north from Sharda group of rocks by the Main Mantle Thrust and on the south by the Hazara Kashmir Syntaxis. This group of rocks has potential for Pb, Zn and Cu. The geochemical survey reflects high anomalous values for Pb, Zn and Cu along this belt.

Hydrothermal and Strata Bound Type Tin - Tungsten Mineralization

Hydrothermal and/or strata-bound type of Tin -Tungsten mineralization is expected in the pegmatites and aplite rocks and meta-sedimentary belt at Oghi area of district Mansehra. Tungsten mineralization in pegmatites is already known in the area. Tungsten (W) is also found anomalous in stream sediment samples of this area. Particles of scheelite ($CaWO_4$) have also been observed in stream sediments of this area since mid-nineteen fifties. (F. Siddiqui -personal observation)

Pb-Zn-Cu Mineralization

Occurrences of Pb-Zn-Cu have been reported from the belt consisting of Abbottabad and Tanawal Formations in Mansehra, Siran and Unhar valleys, and further southwest in the Khanpur, Langrial, and Darban area of district Haripur in the south of Hazara. The important structural features of the area are the Main Boundary Thrust, Khairabad Fault, Murree Fault and Nathiagali Fault. The possible occurrence of Pb, Zn and Cu mineralization is further supported by the anomalous analytical results from the drainage geochemical samples. MINORCO chemical results are anomalous in Bi, Zn, Hg, Au, Pt, Pd, Cd, Ba and Ag. On the basis of geochemical anomalies, the area is further subdivided into Mira Tarla Block, Langrial Block and Bagra Block. One may look for massive and/or hydrothermal deposits along this belt.

7. Stream Sediments Geochemical Exploration Coverage

7.1 Australia-Pakistan GEMAP Exploration Work

Systematic stream-sediments geochemical exploration coverage of northern Pakistan, including the Chitral region of Khyber Pakhtunkhwa, was initiated by SDA in January 1992, in collaboration with the Australia-Pakistan Gold Exploration & Mineral Analysis Project (GEMAP). Australian International Development Assistance Bureau (AIDAB; now AusAID) sponsored this project. Under the GEMAP (January 1992 to June 1995), groups of Pakistani geoscientists, including the writer were provided with specialized on-site training in the gold fields of Australia and in northern Pakistan. This was to initiate systematic and comprehensive exploration coverage of northern Pakistan for gold and related metallic minerals, in particular, and other minerals in general.

In view of encouraging results of the above GEMAP-designed exploration strategy in Chitral, the work was extended to cover Malakand and Hazara regions to the south of Chitral. As such, the Government of Khyber Pakhtunkhwa, Pakistan has completed first pass stream sediments sampling and analysis of northern part of Khyber Pakhtunkhwa over an area of about 40,000 km^2. Similar work has been done in Gilgit Baltistan to the east of Khyber Pakhtunkhwa.

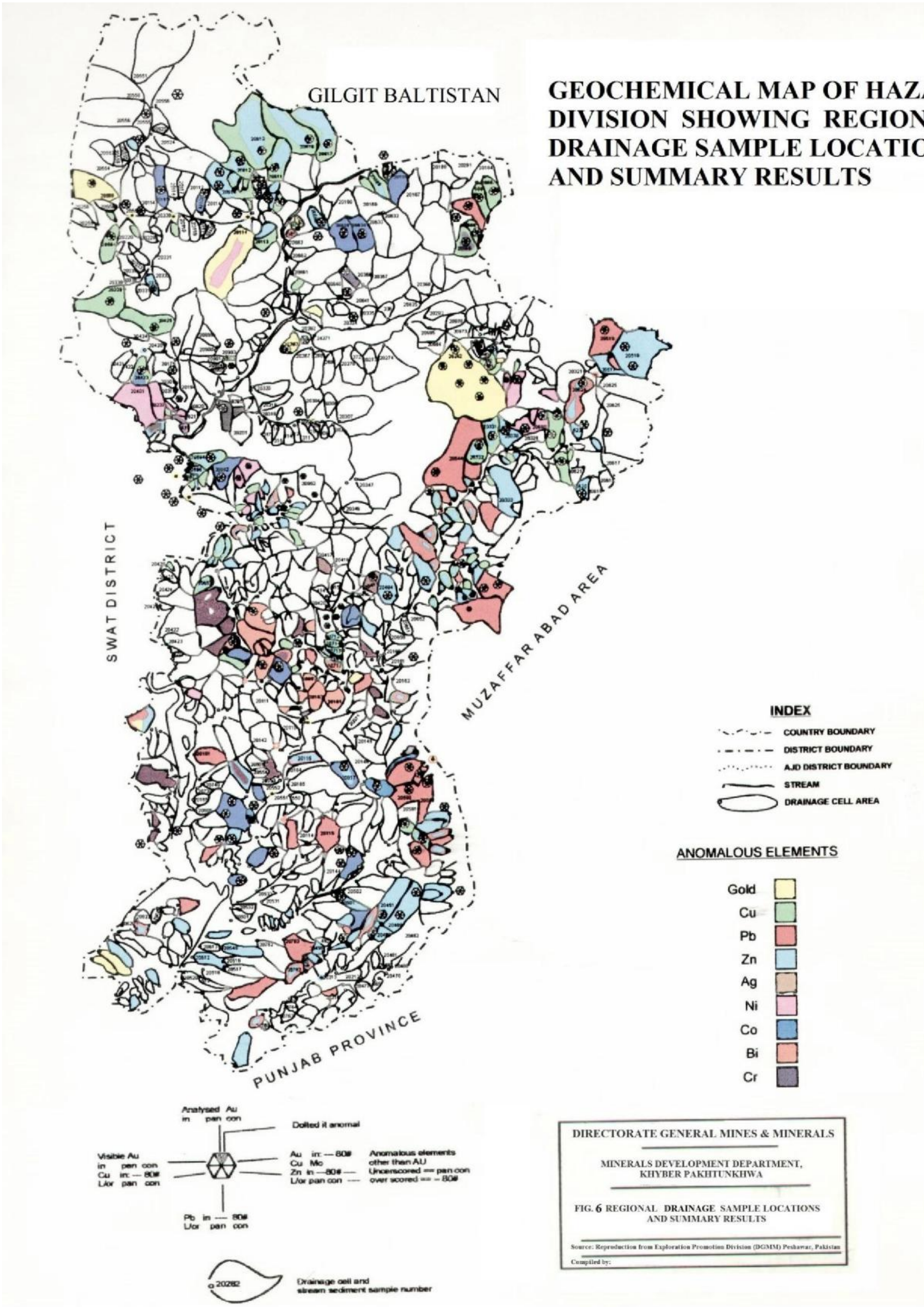


Figure 7 Geochemical map of Hazara Division

7.2 GEMAP Designed Exploration Methodology

The major component of the exploration methodology adopted remains the stream sediments sampling to systematically cover the region. The strategy was based on the premise that any significant outcropping mineral deposits, through natural physical and chemical weathering and erosion processes, contribute components (in the form of rocks, mineral grains and geochemical values) to the sediments of the drainage system in which the deposits are located. Sampling from each site involves collection of panned heavy mineral concentrates and fine fraction of sediments in addition to collection and study of mineralized rock floats.

To reach the source of the mineralization, this methodology involves various stages of drainage geochemical exploration. These stages, from reconnaissance to regional, prospect and deposit scale exploration are briefly explained in the following section.

The results of the stream–sediments data, in integration with geology, known mineral occurrences and other exploration data including remote sensing (aerial photographs and satellite imageries), represent a multi-component system of exploration. The techniques have been found appropriate to demonstrate the mineral potential of the region and a guide to locating viable ore bodies. However, the component of remotely sensed data did not receive adequate attention and needs to be generated and used in coincidence with the drainage geochemical anomalies and metallic mineral occurrences for improved identification of target areas.

7.3 Stages of Geochemical Exploration

The various stages are defined as follows:

a. First Pass Exploration Coverage

Drainage geochemical exploration coverage survey on reconnaissance scale of 1:250,000, in conjunction with remote sensing on aerial photographs and satellite images and use of available geological/exploration data for generation of regional scale follow up exploration targets.

b. Regional Scale Exploration Coverage

Drainage geochemical exploration coverage of regional scale targets with an enhanced density of sampling on scale 1:50,000 plus producing remote sensing data and known minerals occurrences layers for presentation and interpretation of prospect follow up targets.

c. Prospect Scale Exploration Coverage

Infill low energy stream sediments and talus sampling at further enhanced density of 1:10,000 in selected prospect scale targets. Where necessary this may also involve bed rock/chip channel sampling to locate in situ source mineralization. Remote sensing and known mineral occurrences data may also be used for interpretation of deposit scale exploration targets.

d. Deposit Scale Exploration

This is a very exciting stage of exploration and would be dominated by geological mapping of rock assemblages and alteration or mineralization followed by bed rock chip/channel sampling and further followed by geophysical survey depending upon results. The results of this stage of exploration may be disappointing or encouraging for further detailed exploration through drilling etc for resource assessment of the deposits.

e. Laboratory Analysis

Chemical analysis of stream-sediment samples was carried out for 10 elements at MTL. The analytical method involves AAS using aqua regia digestion and DIBK gold extraction after the samples are prepared and pulverized to -200#. The pan cons are dissolved as a whole and analyzed in multiple aliquots of 30 grams while the –80# samples are analyzed in a single batch of 30 grams. The laboratory was equipped with GBC & Philips Atomic Absorption Spectrometer and has the capability of determining the ten elements (Au, Cu, Cr, W, Pb, Zn, Ag, Co, Ni and Bi).

It is worth mentioning that a uniform size of 20 liter sediments is panned from each sample site for comparison of geochemical values from different sites. For further comparison of values, the original weight of pan cons is recorded before the analytical treatment in the Lab. This is required to standardize the analytical values of the varied weight of pan cons. samples to a standard weight of 100 grams pan cons.

7.4 First Pass Exploration Coverage of Hazara Division

The Hazara region, covering about 12000 km2 was subjected to reconnaissance scale geochemical exploration program on a scale of 1:250,000. During this survey a total of 1068 stream sediment samples were collected from all the active streams with catchment area varying from 10 km2 up to 70 km2. These samples comprise of 534 pan con and 534 -80# samples. In addition to the aforementioned stream sediment samples, mineralized float specimens from different streams were also collected. Furthermore, all the information regarding geology, mineralogy of pan cons, alteration, structural features and mineralization visually observed during the survey were also recorded for future interpretation.

All these samples were analyzed in MTL for 10 elements, namely Au, Cu, Sb, Pb, Zn, Mo, Bi, W, Cr, and Co. Based on the chemical analysis, threshold values for these elements are given below:

Table 3 Threshold Values of Chemicals

Name of Element	**Pan Cons Samples (gram/tonne)**	**-80# samples (gram/tonne)**
Au	2	0.05
Pb	60	35
Cu	90	90
Zn	110	100
Ag	0.5	0.5
Co	60	30
Ni	110	80
Cr	300	150
Bi	10	5
Sb	Not enough assays	Not enough assays

All the data was compiled in the shape of ticket books, data summary sheets, geochemical maps, analysis order form and analysis files. Based on the interpretation of this data, in conjunction with satellite data, known mineral occurrences, geological environment and infrastructure facilities, the following regional scale anomalous targets have been established in Hazara Division.

Priority No.	Name of Regional Scale Target	Anomalous Elements
1	Jalkot valley	Au, Cu, Pb, Zn, Co, Ni
2	Kandia Valley	Au, Cu, Pb
3	Kaghan valley	Au, Cu, Pb, Ni
4	Allai valley	Au, Cu, Zn, Co, Ni
5	Kohala area	Cu, Pb, Zn, Au
6	Khanpur- Gor valley	Pb, Zn, Cu
7	Dubair Area	Ni, Co, Pt, Pd, Hg, Cu, Cr, Au
8	Siran valley (Mansehra)	Au, Pb, Zn, Cr, Bi
9	Unhar valley (Oghi)	Au, Cu, Zn, Bi, Cd, W
10	Dassu – Basha Area	Au, Cu, Zn, Pb, Co, Ni, Cr

In the order of priority all the reconnaissance scale exploration targets were subjected to regional scale exploration coverage on a scale of 1:50,000.

7.4.1 Jalkot Valley First Pass

Geochemical Coverage on Scale 1:250,000

During the First phase of exploration on scale 1:250,000 a total of 42 stream sediment samples (21 pan cons + 21 -80#) were collected from main Jalkot River and its tributaries. Visible gold was indentified in the field in a few pan con samples. The chemical analysis results confirmed the gold values in pan con samples collected from Bada sar, Kotgali and Deong nalas of Jalkot River, and in -80# samples from Lui nala. Apart from gold, the valley was also found anomalous for Cu, Ni and Co as per analysis of MTL, and Au, Cu, Ni, Co, Hg, As, W, Sb and Te as per analysis of Ultra Trace Laboratory Australia arranged by MINORCO. Based on these results, in conjunction with geological environment, the area is considered as priority #1 in a total area of 300 km2.

Regional Scale Geochemical Coverage on Scale 1:50,000

During regional scale exploration, on scale 1:50,000, a total of 67 pan con and 77 -80# samples were collected from the anomalous streams already identified during First pass geochemical exploration. These samples were also analyzed in MTL and their results were found encouraging. Furthermore 7 -80# stream sediment samples were provided to Lake Resources of Australia, who analyzed these for 20 elements including PGE. The results of these samples were also found anomalous for Au, Cu, Pb, Zn and Pt. Based on these results, the area is divided into the following prospective sites for further follow-up geochemical and geological investigation.

- Kot Sali site
- Yasingah site
- Karogah site

Local Geology of Jalkot Anomalous Targets

Geologically the area falls in Kohistan Island Arc environment. Locally the geology of the area can be divided into the following lithological units.

- Kamila Amphibolites

- Patan Garnet granulite rocks
- Garnetiferous calc-pelite gneisses.
- Granite
- Darir Migmatites-pelites-psammite Gneisses.
- Sapat Ultramafics

7.4.2 Kandia Valley, District Kohistan First

Pass Geochemical Coverage on Scale 1:250,000

During the reconnaissance scale/first pass exploration coverage a total of 58 samples (both pan con & -80#) were collected from Kandia valley. The sample density/catchment area is between 10 to 70 km^2. These samples were analyzed in MTL for 10 elements and the chemical results show that 13 samples contained gold in the range of 0.3 g/t to 17.65 g/t, while a few of these are also anomalous for Cu and Pb.

Regional Scale Geochemical Coverage on Scale 1:50,000

During the regional scale drainage exploration a total of 190 -80# and 155 pan con samples were collected from the following streams covering about 255 km2.

i. Thani khwar
ii. ii. Soyal khwar
iii. Zambil khwar
iv. Rich nala
v. Mirshahi nala
vi. Bang nala

These samples were analyzed in MTL for Au, Cu, Ag, Pb, Zn, Ni, Co and Cr. Out of these 7 samples were found anomalous in Au, 2 in Pb, 45 in Cu, 78 in Zn, 23 in Co, 19 in Ni and 16 in Cr. Based on the interpretation of the geochemical and geological data the area is considered as priority #2.

Local Geology

Geologically the Kandia valley is located in Chilas Complex. The Chilas complex is a mafic - ultramafic complex, consisting dominantly of gabbro norite, pyroxene diorite-tonalite, olivine gabbros, minor ultramafics (dunite, peridotite, pyroxenites and hornblendites) and anorthosite association. The Kalam volcanics extending from Swat into Hazara are considered very important for porphyry and epithermal gold mineralization. The Kalam volcanic group consists of fore-arc andesitic volcanics of Eocene age. The remnants of Gilgit meta-sediments can be observed in Kandia valley in Chilas complex. Chilas complex is the prominent tectono stratigraphic unit of Island Arc.

7.4.3 Kaghan Valley Anomalous Targets

First Pass Geochemical Coverage on Scale 1:250,000

During this reconnaissance scale drainage geochemical survey, upper Kaghan area was found anomalous in Zn, Cu, Pb and Ni as per analysis results of MTL. The duplicates of these samples analyzed by MINORCO in Ultra Trace Laboratory Australia are found anomalous in Bi, Pb, Zn, Ag, As, W, Au, Cr, Pd, Pt, Co, Te , Cd and Ba.

Regional Scale Geochemical Coverage on Scale 1:50,000

During regional scale drainage geochemical survey a portion from the area i.e. Kawai to Kaghan village was covered through collection of 79 pan cons and 82 –80# stream sediment samples from the anomalous streams covering an area of 250 km^2. These samples were analyzed for Au, Cu, Pb and Zn in MTL. Out of these, 10 samples were anomalous in Cu, 23 in Pb, and 28 in

Zn in pan con and -80# samples. Based on the geochemical results and geological environment the area is considered as priority # 3 and divided into the following prospective sites.

i. Khaian
ii. Ochre
iii. Lahor Banda
iv. Bela Banda
v. Kaghan village.

Local Geology

Geologically the area is composed of Sharda group of rocks such as garnetiferous calc-pelite gneisses, marble, graphitic schist, granite, migmatites, pelites and psammatic gneisses.

Kaghan Formation

It is separated at the north from the Sharda group of rocks by the main central thrust (MCT) and to the south by the Hazara-Kashmir syntaxis from the younger Murree Formation. The rock units comprise of quartzite, schist, granite gneisses, carbonates, mica schist, quartz mica schist, pegmatites and Kaghan slates.

Panjal Formation and Agglomerate Slates

These rocks are widely spread around the apex of Hazara-Kashmir syntaxis in Balakot area. The formation consists of carbonaceous slates, glassy quartz, slate and agglomerate, sandstone and the volcanic greenstone. The rocks of the Panjal Formation are considered to be metamorphosed lava flows and tuffs of intermediate to mafic composition. Mylonite zones are also exposed in the area.

The Higher Himalayan Crystalline Unit

This unit can be divided into two main divisions known as Basement and Cover. Both have certain structural and metamorphic features in common as they have undergone the same deformational events and amphibolites facies crystallization during the Himalayan Mountain building process. The rock units of this formation comprise of quartzites, meta-phyllites, gneisses, granitoids, schists and carbonates.

7.4.4 Alai Valley Geochemical Anomalous Targets

First Pass Geochemical Coverage on Scale 1:250,000

During reconnaissance geochemical exploration stage a total of 20 pan cons and 20 -80# stream sediment samples were collected from the main Allai River and its tributaries. All these samples were analyzed in MTL for 10 elements. As per analysis results of these samples the area is found anomalous in Au, Cu, Zn, Ni.

Regional Scale Geochemical Coverage on Scale 1:50,000

During regional drainage geochemical exploration on Scale 1:50,000, some parts of the area in north-east Natia Khwar, Bana, and Rashang totaling about 212 km^2 were covered through collection of 163 pan con and 167 -80# stream sediment samples. These samples were chemically analyzed for Au, Pb, Cu, Zn, Ni and Cr at MTL. The chemical analysis results indicate that Au was anomalous in 9 samples, Pb in 15, Cu in 8, Zn in 49, Ni in 9 and Cr in 11 samples both in pan cons & -80# samples.

Prospect Scale Geochemical Exploration on Scale 1:10,000

Based on the encouraging results and geological environments the area was subjected to prospect scale geochemical exploration (1:10,000). During this stage of exploration a total of

126 -80# stream sediment samples and 78 chip channel samples were collected. The chemical analysis results indicate 75 -80# and 23 rock samples are anomalous in various elements such as Cu, Pb, Zn, Cr and Ni Based on the geochemical results, geological data and known occurrences the area is considered as priority 4 for further detailed exploration.

Local Geology

The area is located along MMT. To the north of MMT ultramafics and Kamila amphibolites exist while to the south of MMT occur the rocks of northern margin of Indian mass. These are granite gneisses, Tanawal Formation, and Salkhala Formation. Known deposits in the area are lead-zinc, magnetite and copper in Skarn.

7.4.5 Langrial Valley Anomalous Targets

First Pass Geochemical Exploration on Scale 1:250,000

During reconnaissance drainage geochemical exploration program, a number of samples, both pan con and –80#, were collected from this region. All these samples were analyzed in MTL and the area was found anomalous in Pb and Zn. The duplicate samples of this area were also analyzed by MINORCO in Ultra Trace Laboratory, Australia for expanded suite of 32 elements. The MINORCO results are found anomalous in Bi, Zn, Hg, Au, Pt, Pd, Cd, Ba and Ag.

Regional Scale Drainage Geochemical Exploration on Scale 1:50,000

A total of 90 pan con, 112 -80#, and 13 rock samples were collected from this area and were analyzed in MTL for Au, Cu, Pb and Zn. Out of these samples 5 samples are anomalous in Cu, 16 in Pb and 15 in Zn. Based on these anomalies the target area is further divided into the following three blocks.

Mairla Tarla Block, District Abbottabad

Langrial Block (District Haripur)

Bagra Block (District Haripur)

First Pass Geochemical Exploration on Scale 1:250,000

During reconnaissance drainage geochemical exploration program, a number of samples, both pan con and –80#, were collected from this region. All these samples were analyzed in MTL and the area was found anomalous in Pb and Zn. The duplicate samples of this area were also analyzed by MINORCO in Ultra Trace Laboratory, Australia for expanded suite of 32 elements. The MINORCO results are found anomalous in Bi, Zn, Hg, Au, Pt, Pd, Cd, Ba and Ag.

Regional Scale Drainage Geochemical Exploration on Scale 1:50,000

A total of 90 pan con, 112 -80#, and 13 rock samples were collected from this area and were analyzed in MTL for Au, Cu, Pb and Zn. Out of these samples 5 samples are anomalous in Cu, 16 in Pb and 15 in Zn. Based on these anomalies the target area is further divided into the following three blocks.

Mairla Tarla Block, District Abbottabad

Langrial Block (District Haripur)

Bagra Block (District Haripur)

Local Geology

The area falls in the geological environment of the Indian Mass and the important structural features are the Main Boundary Thrust (MBT), Khairabad Thrust, Murree and Nathiagali Faults passing the area, in between Mansehra and Murree, strongly affecting the geology of the area.

7.4.6 Siran Valley Anomalous Targets

First Pass Exploration Coverage on scale 1:250,000
The area is established as anomalous target for Pb, Au, Cr, and Bi on the basis of First pass exploration stage (1:250,000) geochemical samples assays conducted at MTL The duplicates of these samples were also analyzed by MINORCO in Ultra Trace laboratory Australia for expanded suite of elements (21 samples), wherein the area was found anomalous for As, Sb, Ag, W, Au, Pt, Zn, Te and Pd. This anomalous target is placed at priority # 8.

Regional Scale Coverage on Scale 1:50,000
Regional drainage sampling of the Siran River and its tributaries was partly completed through collection of 59 pan con and 70 -80# stream sediment samples. These samples were analyzed in MTL for four elements i.e. Au, Cu, Pb and Zn. The chemical results indicate that only 6 samples were found anomalous in Cu, Pb and Zn. Based on these results the area can be divided into the following two sites.

- Dadar-Sum area
- Pharhanas-Chajan area

Local Geology
The Siran valley lies within the geological environment of Indian mass, where Panjal Fault (Khairabad) passes through this area. The rock units exposed in the area are Mansehra granite and dolerite dykes. Meta-sedimentary rocks are Hazara Slate Formation, Tanawal Formation and Abbottabad Formation.

7.4.7 Unhar Valley Oghi Geochemical Anomalous Targets

First Pass Geochemical Coverage on 1:250,000
The area is found anomalous for Au, Cu, Zn, Bi, Cd and W on the basis of chemical results of reconnaissance geochemical samples collected in this area. The area is considered as priority #-9.

Regional Geochemical Exploration on scale 1:50,000
During the regional scale drainage geochemical survey on scale 1:50,000 a total of 150 stream sediment samples comprising of 75 pan con and 75 -80# were collected and covered about 350 km^2. These samples were analyzed in MTL for Ni, Pb, Cu, Zn, Fe, and Mn. Out of these samples 22 samples were found anomalous in Pb, 22 in Zn, and 6 in Cu.

Based on these results and the geological environment, Jodah Katha area near Shergarh with 50 km^2 area was selected for prospect scale geochemical exploration for Pb, Zn and Cu. However, work could not be continued due to lack of funds.

Local Geology
The area consists of the following main geological formations:

- Tanawal Formation
- Mansehra granite
- Younger intrusives

The porphyritic granites are light colored and medium to coarse grained. Some tourmalines are also found in this granite in scattered form. Aplite bodies and diabase dykes are frequently encountered and cut the other rock units in this area. Some scheelite has been identified in many samples under mineralogical studies collected from Oghi and Gidarpur areas where geology favors such mineralization. The area has potential for scheelite and warrants detailed exploration.

7.4.8 Dashu Basha Geochemical Anomalous Targets

First Pass Geochemical Exploration Coverage on Scale 1:250,000

During reconnaissance scale geochemical survey on scale 1:250,000 a total of 57 pan con and 75 -80# stream sediment samples were collected, and covered about 900 km^2. All these samples were analyzed in MTL. The results show that the area is anomalous in Au, Cu, Zn, Co, Ni and Cr.

Regional Geochemical Exploration on Scale 1: 50,000

Based on the encouraging results obtained during Reconnaissance scale geochemical exploration, the area was subjected to follow up geochemical exploration on scale 1:50,000. During this stage of exploration, a very small portion of the area was covered by collection of 9 pan con and 27 -80# stream sediment samples, and covered 86 km2. These samples were analyzed for Au, Cu, Ag, Zn, Co, Cr and Ni. Out of these 17 pan con and 16 -80# stream sediment samples were found anomalous in Au, Cu, Co, Ni and Cr.

Local Geology

This area covers the northern most part of Hazara division. The rocks exposed in the area consist of Chilas complex which is mafic ultramafic stratiform plutonic complex, consisting dominantly of gabbros, norite, pyroxene diorite– tonalite and olivine gabbros with minor ultramafic and anorthositic composition. The roof zone is comprised of country rocks from either the Kamila amphibolites or the Gilgit Complex of meta-sedimentary rocks.

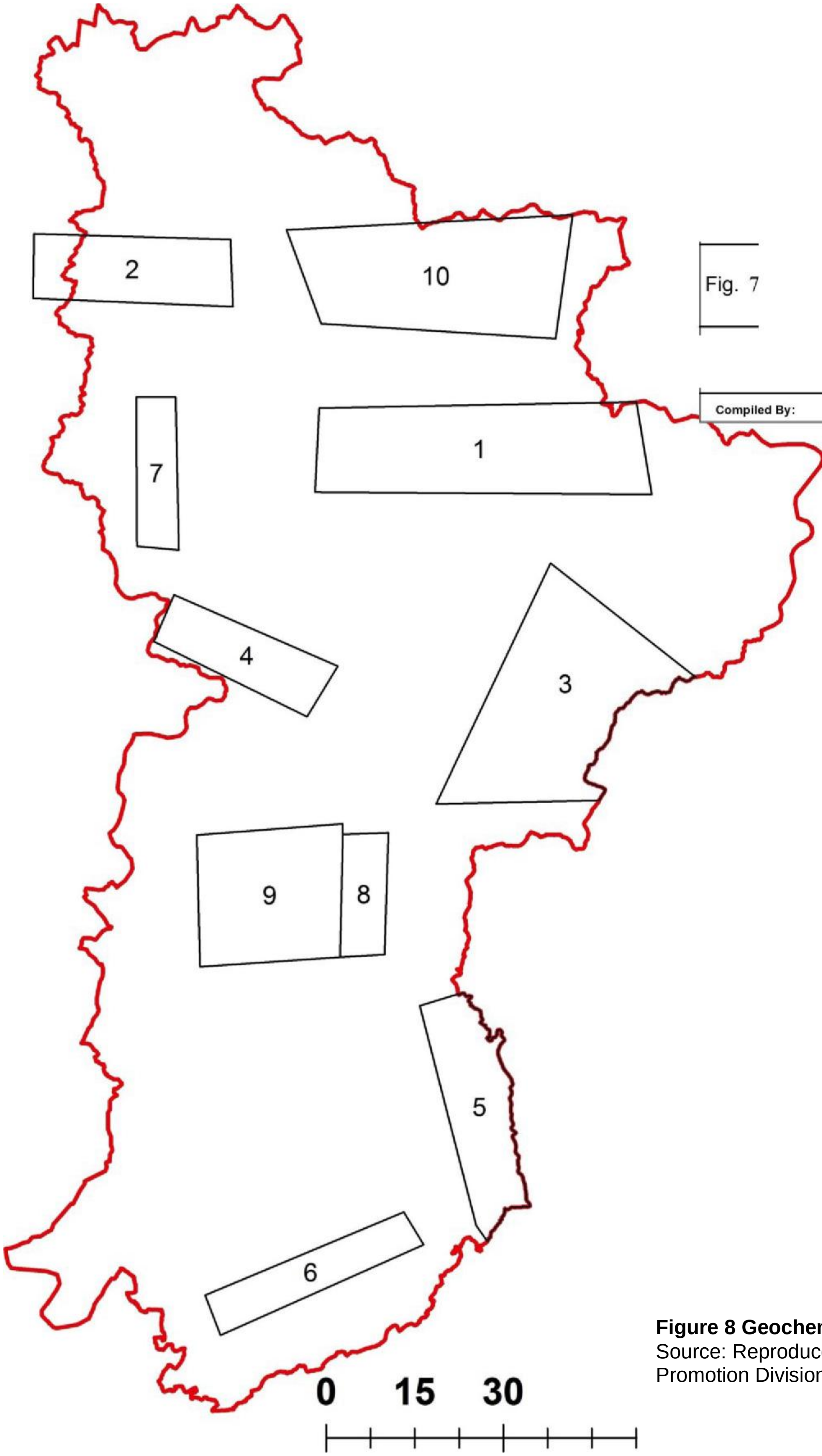


Figure 8 Geochemical Target Map of Hazara
Source: Reproduced from Exploration Promotion Division (DGMM Peshawar, Pakistan

Table 4 Key To Figure 7

1	Jalkot Valley Au, Cu, Co
2	Kandia Valley Au, Cu, Zn
3	Kaghan Area Pb, Zn, Cu
4	Allai Area Zn, Cu, Pb, Au, Co
5	Kohala Area Pb, Zn
6	Havelian-Khanpur Area Pb, Zn
7	Dubair Area Ni, Cr, Co, Au, Cu
8	Siran Valley Au, Pb, Zn, Cu, Bi
9	Unhar Oghi Area Au, Pb, Zn, Cu, Co, Bi + Scheelite
10	Dassu to Basha area along Indus/KKH for Au, Cu, Zn, Co, NiandCr

7.5 MINORCO Involvement

MINORCO was a subsidiary company of Anglo–American & De Beers, who owned exploration and mining operations in South Africa and South America, and was seeking metallic-minerals properties in Pakistan, Central Asia and Mongolia. On the basis of encouraging results obtained during drainage geochemical survey in district Chitral, Hazara division and Malakand division (Districts Swat, Shanglapar, Bunair , Malakand Agency), MINORCO signed a one-year MOU with Government of Khyber Pakhtunkhwa, Pakistan in June, 1997. As per MOU, the duplicate GEMAP samples of pan cons & -80# stream sediment samples, totaling about 4000 from the aforementioned regions, were provided to MINORCO for further analysis and interpretation. These samples were considered as major exploration resource, the potential value of which had not been fully explored because of the restricted nature of original analytical program. The objective of MINORCO program was to reanalyze the drainage samples for a greater range of elements and to lower detection limits that was not possible at MTL, Peshawar. The object was to enable more rigorous definition of anomalies, including the application of multivariate statistical techniques. MINORCO also arranged visits of the experts including Dr. Richard Sillitoe of UK and Richard Mazzucchelli of Western Australia (WA) along with others to the area for assessment of the known prospects. The stream sediments geochemical data as such, was upgraded by virtue of involvement of MINORCO. This led to generation of an expanded database of long lasting value for follow-up exploration of selected targets of gold and related metallic minerals over an area of 40,000 km² of northern part of Khyber Pakhtunkhwa including Hazara region. The work carried out in pursuit of this objective is described in the following section.

Chemical Analysis

Under the joint venture, MINORCO re-analyzed the duplicates of stream sediment samples for an expanded suite of elements (32 elements) mostly at mg/t level in the Ultra Trace laboratory, Perth, WA. The pan cons samples were analyzed only for Au, Pt and Pd and the fine fraction stream-sediments (–80# samples) were analyzed for all the 32 elements.

Interpretation of 1:2,000,000 Plots

Dr. Mazzucchelli, the MINORCO exploration geochemist, merged the field data of the stream-sediments with the Ultra Trace analytical report and carried out statistical analysis for interpretation of drainage geochemical anomalies. The interpretations were presented on plots at a scale of 1:2,000, 000 which show the distribution of geochemical values of all the elements analyzed over the entire concentration range, using spectral color scheme distinguishing anomalous values from background dispersion pattern. The plots prepared both for single elements and 10 factors of multi-elements distribution, reflect aspects of regional geology as well as areas of potential mineralization. The histograms of the geochemical data and

1:2,000,000 plots are available with DGMM. The salient features of the interpretation based on 1: 2,000,000 plots are:

The results obtained were statistically interpreted. The correlations which exist between the elements form the basis for Factor analysis. Factor analysis essentially summarizes the multi-element data in to ten factors which together account for 68% of the total variance. The dominant element making up each of the various factors can be listed in order of their respective influence as follows (next page):

Table 5 Factor Analysis

Factor 1	Fe- Mn-V-Zn-Ti
Factor 2	(Ni-Cr-Mg/Ca-Co)-V
Factor 3	Cu-Mo-Te-(Ti-Hg)
Factor 4	Se-Nb-Ti-Sn
Factor 5	Sb-Pb-Ag-(Cd)-W
Factor 6	(W-As—Bi)-Sb-K/Na
Factor 7	(Rb/Sr-Ti-Zn-Sn)-Cd
Factor 8	Ba-P-Zn—Cd-(Hg)
Factor 9	(Auc-Aud-Ptc-Pdc)-Sb
Factor 10	Hg-Cd—(Ba)-Ptc-K/Na

Factors 1, 2, 4 and 7 appear to reflect aspects of the regional geology, while the remaining factors 3, 5,6,8,9 and 10 may be indicative of mineralization.

In addition to the 1:2,000,000 plots, anomaly plans for the more important targets and pathfinder elements were plotted on a scale 1:250,000 (plan 1-16). These plans outline the threshold value based on catchment site. The expanded analytical data shows many features of interest, which can be derived from the Tables, Figures and Plans in the MINORCO report available with DGMM.

The dispersion pattern evident in the 1:2,000,000 plots for single element reflects aspects of the regional geology as well as indicating areas of potential for mineralization. The dispersion pattern for a number of elements closely reflects aspects of the regional geology. Arsenic is strongly enriched over much of the Eurasian plate, while Ti concentration is lower than the two units (Kohistan arc & Indian Mass). Ba, K/Na, Pb, Rb/Sr, Sn and Ti tend to show high background values within Eurasian and Indo-Pak Plate, relative to rocks of Kohistan Arc.

Co, Cu, Fe, Mn and V show the reverse trend, with higher background in the arc sequence relative to Indian and Eurasian Plate. Background for Se is relatively high in Indo-Pak Plate. Concentration of Cr, Mg/Ca and Ni closely follows the MMT and MKT, no doubt reflecting alpine type of ultramafic bodies along these major structures. Elevated values of these elements (Cr, Mg/Ca, Ni) with Co and Cu are also evident in southern part of Kohistan arc, coinciding with mafic/ultramafic rocks of the Chilas complex and Kamila amphibolites. These relationships are to some extent summarized in plots for the first two factors.

Factor-1 Fe-Mn-V-Zn-Ti has strong negative loadings for elements having high concentration in the Kohistan Arc and showing strong lows in the core of this geological unit. This factor provides very good discrimination between the major geological units present in the area, covered by the survey.

Factor-2 (Ni-Cr-Mg/Ca-Co)-V has strong negative loadings for the elements of mafic/ultramafic association, so low values are most prominently following major thrust faults, where alpine ultramafic rocks are known to occur. Exception to this is at Dassu (Chilas complex).

Factor 3 Cu-Mo-Te-(Ti-Hg) represents porphyry copper type mineralization. The remaining factors represent various style of alteration mineralization and none are indicative of classical arc association. The results of factors analysis should be used in conjunction with single element plots to guide follow up work.

Factor-4 Se-Nb-Ti-Sn shows general elevation throughout the Indo-Pak Plate, as well as local environments around to the east of Malakand, the remaining factors appear to represent local rather than regional geological association. The composition of Factor-4 is suggestive of pegmatite or carbonatitic association.

Factor 5, 6 and 8, made up of the various combinations of base metals and path finder elements highlight a series of discrete anomalies, mostly along the fault zones to the north of NSZ, but also in the Precambrian basement to the north east of Abbottabad.

Factor-7, the component of Factor-7 is suggestive of potassic alteration assemblages.

Factor-9 is dominated by the precious metals, but the absence of path finder elements and spotty distribution of high (negative) scores suggest that this factor represents placer accumulation rather than primary deposits.

Factor-10 is an enigmatic combination of elements, not indicative of known mineral association. Despite the widespread occurrence and abundance of Au in both pan cons and -80# stream sediments , generally none of the factors suggest an association with typical path finder elements suites, such as As-Sb-Hg-W which are characteristics of primary gold deposits. Despite this there are areas in survey area where Au coincides with path finder response.

7.6 Plots Representing Areas of Potential Mineralization

Interpreting the data for target areas of potential mineralization, the prominent anomalies in Hazara region are summarized as under:

- Factor-2 which incorporates Ni (Cr and Co) does not include chalcophile pathfinders such as Cu, Te or Pt and Pd. This may be due to the low density of sampling to date and it should be noted that there are relatively high concentration for both Ni and Cu in the zone to the north of MMT associated with the Chilas complex, where more detailed exploration could be warranted.
- Factors 5, 6 and 8, made up of the various combinations of base metals and path finder elements highlight a series of discrete anomalies, mostly along the fault zones to the north of NSZ, but also in the Precambrian basement to the north east of Abbottabad.
- The only factor with significant loading for Au is factor 9, which also includes Pt & Pd. This factor suggests placer type concentration. Despite this there are areas in the survey area, where Au coincides with path finder response. Two such areas are an extensive Au (-80#) anomaly, associated with MMT south east of Dassu (with As & Cu) in Hazara division, and the other areas (Ashret & Dommel Nisar) fall in Chitral region.
- Other factors, although often reflecting rather bizarre elements combination, no doubt do represent areas of unusual geology, the explanation for which would emerge from further investigations. In some cases the explanations could include mineralization of interest.

7.7 EPD Interpretation Work

The Exploration Promotion Division (EPD) of Khyber Pakhtunkhwa Directorate General Mines & Minerals has digitized the geochemical data in ESRI's Arc GIS as part of systematic documentation and storage of available exploration-data of the Province. The geochemical data of Hazara has been interpreted into 10 suites of anomalies of metals in coincidence with known metallic-mineral occurrences along geological belts of the accreted tectonic blocks. The geochemical map of Hazara showing distribution of metal anomalies, reproduced from open file of EPD is placed at Table-4. The interpretation of the follow-up exploration targets is based on integration of the following data:

- Topographic maps - Survey of Pakistan top sheets.
- Geological map; Jan & Kazmi (1978) of northern areas as base map.
- Geological reports, literature, maps, published and unpublished data of Hazara region.
- Minerals location maps - Published data as well as personal involvement as part of exploration activities in Hazara.
- Interim and final geochemical reports based on reconnaissance, regional and prospect scale drainage geochemical exploration data of Regional Mineral Exploration Project for gold & base metals Hazara division.
- Statistical analysis, MINORCO's statistical analysis for global threshold values of gold and base metals (32 elements) over northern part of Pakistan worked out by Dr.Mazzucchelli, Consultant exploration geochemist, Perth, WA.

Table 6 Summary of the Interpretation of First Pass Exploration Coverage for Gold & Base Metals in Hazara Division

Tectonic Block	**Geological** Belt	**Anomalous** Metals/Path Finders	**Known Mineralization**	**Possible Exploration** Targets
	Chilas Complex.	Cu, Au, Cr, Ni, Co, Zn, Pb	• Copper (showings in the form of Malachite, Chalcopyrite) • Chromite pods, veins, disseminations	• Layered type Ni & Co •Hydrothermal Cu, Pb, Zn •Potential for Stillwater type massive and disseminated Cu,Ni sulphides. •Bushveld type Fe-Ti-V deposits •Podiform Chromite
	Kandia Volcanic Belt	Cu, Au, Zn, Pb	•Scattered showing of malachite and azurite along volcanic belt •Chalcopyrite associated with quartz veins in volcanic rocks	•Porphyry Au-Cu-Zn mineralization •Epithermal Au-Cu mineralization •Structurally controlled gold and base metals mineralization
	Mixed sheared Zone			•Fault related Au, Cu, Pb, Zn
	Kamila Amphibolites	Au, Cu–Ni , Zn, Co	•Copper showing in the form of Malachite, Chalcopyrite	•Hydrothermal structurally controlled metamorphogenic Au & Base metals
	Jijal complex	Au, Ni, Cr, Au, Pt, Pd	•Podiform chromite deposits in Manidara •Cu -Au mineralization associated with Hornblendites at Kuali khwar •Au, Pt and Pd mineralization in basic to ultrabasic rocks	•Podiform chromite •Merensky type Pt & Pd •Cyprus type Gold and base metals •Structurally controlled gold and base metals mineralization
	Southern Suture Zone	Cr, Cu, Ni, Fe	•Podiform chromite Associated with dunite and serpentinite rocks •Ni - Fe mineralization in the ophiolite melange zones.	•Cyprus Au, Cu • Besshi type Volcanogenic Massive Sulphide •Structurally controlled fault related Au mineralization along MMT

Tectonic	**Geological**	**Anomalous**	**Known Mineralization**	**Possible Exploration**
	Allai Mélange	Au, Zn, Pb, Co, Ni	•Fe, Cu , Zn and Cu as	•Hydrothermal type of
	Zone		skarn at the contact of carbonate rocks.	gold & base metals mineralization •Metasomatic (Skarn type)
	Himalayan	Pb, Zn, Fe, Bi, W	•Pb-Zn, mineralization	•Sedimentary Exhalative
	Crystalline		in metamorphic rock	deposits
	Zone		assemblages at Lahor & Pazang area along the northern margin of Indian mass •Magnetite-pyrrhotite mineralization along belt parallal to Pb-Zn mineralization •Scheelite mineralization in pegmatites and aplites traversing Oghi	•Stratiform massive sulphides •Metasomatic Skarn type Iron, lead mineralization •Hydrothermal vein deposits •Structurally controlled sulphide mineralization
			Granite.	
	Kaghan Meta-	Pb, Zn, Cu		•Massive sulphides
	Sedimentary			
	Belt			
	Foreland fold –	Pb, Zn, Fe	•Hematite deposits of	•Mississippi type
	Thrust belt		Langrial	Sulphide mineralization
	(NW		• The occurrences of	•Sedimentary ore
	Himalayas)		sedimentary hosted Pb, Ba, Cu and Fe sulphides have been found as clusters in a narrow zone of about 10 km in between Alluli and Hill villages in district Haripur	•Structural controlled Hydrothermal deposits, epigenetic •Hydrothermal vein type Au & sulphide deposits

8. Gemstone Resources

Gemstone occurrences are known in Mansehra district of Hazara division. The most prominent one is gem quality peridot, hosted by dunite rock in Sapat, and Besal areas of Kaghan valley. Geologically the dunite rock belongs to the Sapat ultramafic complex located along MMT at the boundary of District Kohistan in the west and Mansehra in the east, and further extended in the north-east direction to Babusar in Kaghan valley. The area has good potential for gem quality peridot, but due to primitive mining by the locals these precious deposits may be damaged/exhausted.

Metasediments hosted corundum is also reported in different localities in Kaghan-Naran valley. These are opaque, and so far no gem quality corundum in shape of ruby or sapphire has been found in the area. The corundum mineralization is associated with marbles and schists of Salkhala group. Aquamarine is also reported from the same area but no gem quality is found in the region.

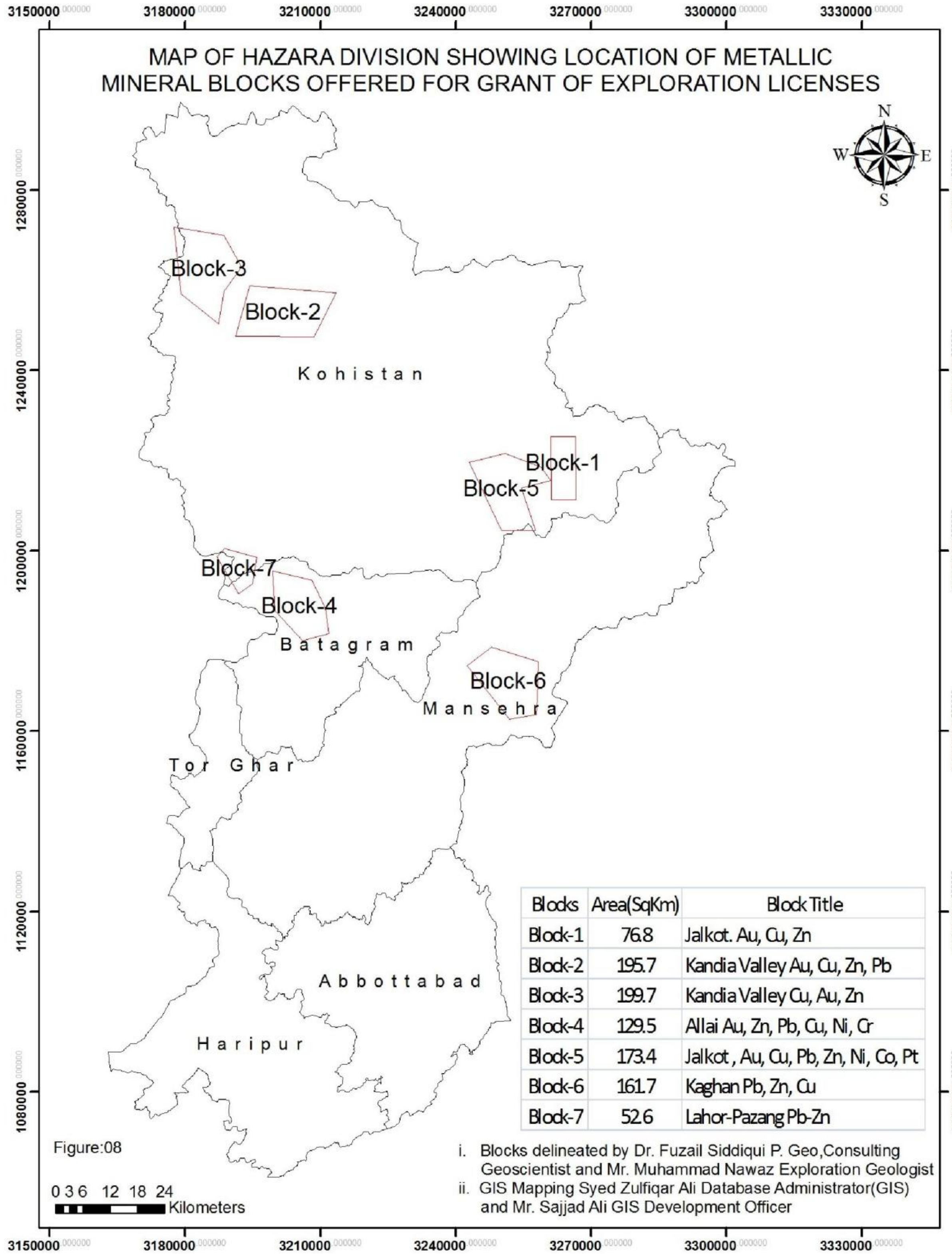
A few occurrences of aquamarine with or without Topaz and tourmaline are reported/known within Mansehra granite. Prospecting is needed for further localities along Jijal Sapat ultramafic rocks on the border of Kohistan and Mansehra districts and along MMT further in the east in Kaghan valley.

Geologically the rock belt of ophiolite along southern Suture Zone at Shangla (Gujar kili), Charbagh, Mingora and Shamozai mélange zones has potential for the known Swat emerald mineralization. The talc carbonate rocks in association with the serpentinite blocks, are good host rocks for emerald. The same belt in the Hazara division may also have potential for emerald.

9. Mineral Blocks Offered for Exploration Licenses

Several small scale mining concessions, mainly dimension stones (granite), industrial minerals and a few metallic minerals concessions i.e chromite, iron, copper and lead have been granted to local parties in Hazara division. The Directorate General Mines and Minerals has kept the other areas reserved for grant of the same for Exploration Licenses through a process of competitive bidding to select sound parties with the experience and resources for exploration and development of metallic minerals and gemstones.

Presently, the writers have identified seven (7) Blocks of metallic minerals based on the interpretation of available exploration data, including geological environment, known metallic minerals occurrences and the results of drainage geochemical exploration. These blocks are being offered for grant of exploration licenses to potential investors as per table-4.



Blocks	Area(SqKm)	Block Title
Block-1	76.8	Jalkot. Au, Cu, Zn
Block-2	195.7	Kandia Valley Au, Cu, Zn, Pb
Block-3	199.7	Kandia Valley Cu, Au, Zn
Block-4	129.5	Allai Au, Zn, Pb, Cu, Ni, Cr
Block-5	173.4	Jalkot , Au, Cu, Pb, Zn, Ni, Co, Pt
Block-6	161.7	Kaghan Pb, Zn, Cu
Block-7	52.6	Lahor-Pazang Pb-Zn

Figure 9 Map of Hazara Division Showing Location of Metallic Minerals

Table 7 Summary of Geology and Mineral Potential of Hazara Division

Tectono-stratigraphic belt	Related Intrusives	Geological Modeling	Metallogenic Modeling: Conceptual	Metallogenic Modeling: Empirical (based on drainage geochemistry and geology)	Know Mineral Occurrence: Metallic Minerals	Know Mineral Occurrence: Non metallic (dimensional/ gemstone potential)	Others
Chilas Complex Late Jurassic to Cretaceous comprises of intermediate to basic and ultra-basic rocks.	Kohistan batholiths and later intrusion in Chilas complex	. Andean type . Collisional and subduction related	. Porphyry Cu (Au, Mo) and related distal and proximal systems . Bushveld type Fe-Ti-V deposits . Stillwater type massive Cu-Ni sulphides . Epithermal Au-Ag . Structural control Gold and base metals . Merensky platinum group elements . Podiform Chromite	Structural control Au-Cu-Zn mineralization. Epithermal Au-Ag . Merensky type Platinum group mineralization Podiform chromite . Hydrothermal Cu, Pb & Zn . porphyry Cu(Au, Mo) and related distal and proximal systems	. Sporadic showings of copper mineralization . Chromite mineralization associated with mafic-ultra-mafic rocks . Malachite showings in volcanic rocks, Kandia valley. . Platinum group elements (Pt & Pd) associated with ultra-mafic rocks	. Norite - pyroxenite rocks can be used as dimension stone. . Serpentinite rock can also be used as dimension and decorative stones	.
Kamila Amphibolite & Amphibolite shear zone Derived mainly from volcanic and plutonic rocks of 83-80 Ma	Later intrusion in amphibolites belt	. Island arc	. Fault-related structurally controlled Au & base metals	. Fault-related structurally controlled metamorphogenic type Au-Ag and base metals. . Platinum group elements & Nickel sulphides	. Sporadic showings of malachite & chalcopyrite. . Structural control Cu, Au mineralization found in sheared zones within amphibolites rock at Kauli area	. Epitode bearing banded amphibolites can be used as dimension stone	
Kohistan complex/Patan garnet granulites. High pressure basic to intermediate rock with ultra-basic	Later intrusion	. Island arc	. Podiform chromite . Nickel sulphides . Fault related structurally controlled Au & base metals	. Nickel sulphides . structurally controlled Au & base metals	. Scattered showing of malachite	. Garnet granulite rocks have potential for dimension stones. . Hornblendite rock with disseminated almandine garnet	

bodies (Mid Cretaceous to Tertiary)						can also be used as dimension stone.	
Jijal Complex Ocean floor cumulates of ultra-basic rocks of Mid Cretaceous to Tertiary.	Besham and Lahor granite	. Island arc	. Cyprus type massive sulphide deposits . Podiform Chromite . Bushveld type Fe-Ti-V deposits . Merensky type PGE	. Cyprus type polymetallic massive sulphide. . Merensky type PGE (Pt & Pd) . Podiform chromite	. Au, Pt, Pd with ultra-basic suite of rocks . Podiform Chromite. . Sporadic showing of malachite	. Large masses of Hornblendite deposits has potential for dimension stone	
Southern Suture Zone Ophiolite belt and mélanges along MMT With Cretaceous age	May be related to Besham granite, and Lahor granitic rocks	Subduction related	. Fault related structurally controlled Au-Ag. . Besshi type volcanogenic massive sulphide . Cyprus type massive sulphides •	. Fault related metamorphogenic type poly-metallic veins. . Podiform chromite . Cyprus type massive sulphides	. Chromite mineralization associated with ultra-basic rocks . Copper mineralization associated with quartz veins and shearing control.	. Dimensional stone potential in shape of serpentinite. Peridotite . Gemstone clan of beryl, corundum & peridot	Talc-soap stone deposi at Barka
Allai Mélange Zone	Thakot intrusive	Subduction related	. Podiform chromite . Hydrothermal Au & base metals	. Metasomatic (skarn) Fe, Cu, Zn & Pb	. Chromite deposits associated with ultra-basic rocks. . Fe-Cu-Zn skarn	. Talc deposits	
Higher Himalayan crystalline basement rocks Precambrian to Paleozoic basement and cover sequence rocks between mylonite zone in the south and MMT in the north.	Besham and Lahor granite. Thakot granitoid	Subduction related	. SEDEX type massive sulphide deposits.	. SEDEX type massive sulphides of Pb-Zn deposits	. Pyrite dissemination in Fe-rich quartz veins and Pb-Zn mineralization associated with meta volcanics at margin of Indian mass at Pazang & Lahor site . Skarn Cu, Pb, Zn, Fe at Pazang & Lahor sites	. White and grey marble . Granite potential . Other dimensional stone potential as basic dikes. . Corundum and beryl mineralization associated with carbonate rocks	Graph ite deposi Kagha valley. Gemst e potent in Kagha valley
Kaghan meta-	**Besal,**	**Shelf type**	**. Massive sulphide**	**. Mississippi type massive**	**. Oghi scheelite**		**Coal,**
sedimentary belt	Mansehra and	sediments		sulphides			graphi te,
	Oghi granite	hosted base		. Hydrothermal vein Au-			feldsp ar
Proterozoic to		metals		Cu-Pb-Zn deposits			deposi ts

Archean meta-				. Stratabound Scheelite			
sedimentary rocks							
occupy a linear belt							
between Kaghan in							
east and Oghi in the							
west.							
Foreland fold belt	Mansehra	Fault related	. Hydrothermal vein	• Hydrothermal vein type	. Pb-Zn mineralization	. Barite deposits	Coal,
(NW Himalayas)	granite	structural	type Au, Cu, Pb, Zn	Au, Cu, Pb, Zn	associated with quartz	. Phosphate	Graph ite.
		control.			veins in district Haripur.	deposits	Silica
Precambrian to					. Fe-Cu-Zn at Langrial	. Sherwan	sand
Paleozoic						soapstone	
sedimentary rock						deposits	
sequence exposed						. Mn deposits	
between Main						. Magnesite	
Boundary Thrust &						deposits at	
Panjal Thrust						Sherwan	

Table 8 Summary of the Geology, Known Metallic Minerals & Geochemistry of the Proposed Blocks for Grant of Exploration Licenses through Competitive Bidding in Hazara Division

Block No (Area)	Geology	Anomalous Metals/Path Finders	Known Mineralization
Block-01 Jalkot (76.8 Km^2)	Dominantly the rock sequence of Kamila Amphibolites with subordinate pyroxene granulites. Various plutonic rocks intermediate to basic in composition (diorite to granodiorite and gabbros have intruded the amphibolites belt at places.	• Cu-Au-Pb-Zn • Hg • As • W • Sb	• Sporadic showing of copper mineralization • Copper is also associated with quartz veins and sheared zones.
Block-02 Kandia Valley (195.7 km^2)	Geologically the area falls in Chilas Complex having upper contact with Kohistan Batholiths and lower contact with Kamila amphibolites. The Chilas Complex is mafic ultramafic complex, consisting dominantly of gabbro-norite, pyroxene diorite–tonalite, olivine gabbros, with minor ultramafic and anorthosite associations. The volcanic rocks in Kandia valley, possibly the eastern extension of Kalam volcanics is geologically very important for certain type of mineral deposits	• Cu-Au-Zn-Pb-Ni-Co • Sb • W • As • Bi	• Scattered copper mineralization in the form of malachite & azurite • Chalcopyrite associated with quartz veins.
Block-03 Kandia Valley (199.7 km^2)	As for Block-2	• Cu-Au-Zn • Sb • W • As • Bi	• As for Block-2

Block-0 4 Allai (129.5 Km^2)	The rocks belong to Allai ophiolitic Mélange zone along MMT, comprising of serpentinite, and peridotite. To the south are exposed Precambrian meta-sediments along with inter-bedded carbonate rocks with granitic to granitoid intrusion (Salkhala Formation). Beside the above, graphitic schists are also found in the area. The contact between the Ultramafic and the metasediments is faulted one. Furthermore the Main Central Thrust (MCT) of Kaghan valley also passes through this area.	• Au-Cu-Cr-Fe-Ni-Zn-Mo	• Magnetite as skarn • Podiform chromite • Mo & Zn as Skarn
Block No (Area)	**Geology**	**Anomalous Metals/Path Finders**	Known Mineralization
Block -05 Jalkot (173.4 km2)	Amphibolites with subordinate pyroxene granulite. Various plutonic rocks intermediate to basic in composition (diorite to granodiorite ans gabbros have intruded the amphibolites belt at places. The upper part occupies the boundary of Kohistan with Mansehra district, and consists of the Sapat Utramafic complex and meta-sediments of Sharda group. Geochemically anomalous sites are at Kot Gali, Yasingah and Karogah.	**• Cu-NiZn-Pt-Te** **•Hg** **•As** **•W** **•Sb**	• Sporadic showing of copper mineralization at places • Copper is also associated with quartz veins and sheared zones

Block-06 Kaghan (161.7 Km2)	The metasedimentary rocks of the area consist of Kashmir sequence comprising of Murree Formation, Paras Formation, Kaghan Formation, Tanawal Formation, Panjal Formation, Rajwal Formation and Sharda group consisting of Naran, Gorian Katha, Besal, Lalusar, Burawal gneisses, granite and amphibolites. The major structural features of the area are Panjal Fault and Main Central Thrust which separate the above groups of rocks from each other	• **Pb-Zn-C u**	• Mississipi type massive sulphide deposits • Metamorphogenic Cu- Pb-Zn mineralization • Structurally controlled sulphide deposits.
Block-07 Lahor-Pazang (52.6 km2)	The mineralization occurs in metamorphosed and complexly deformed volcanic rocks having sedimentary exhalative origin. These are in fault zone in highly tectonised region on the northern margin of Indian mass close to MMT.	• **Pb-Zn-Cu-Ni**	• Pb-Zn, mineralization in metamorphic rock assemblages at Lahore & Pazang area along the northern margin of Indian mass • Magnetite-pyrrhotite mineralization along belt parallel to Pb-Zn mineralization

Muhammad Nawaz Khan Dr. Fuzail Siddiqui
Exploration Geologist Consulting Geoscientist

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